The development and application of creative printmaking processes for the decoration of blown glass

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Abstract

Embedding screenprinted transfers is one of several processes that can be used by artists as a means of expression to decorate blown glass forms. When screenprinted transfers are embedded into layers of glass and inflated, the imagery can be affected by a number of factors that limit the process. These limitations can include stretching and distortion of imagery, loss of density resulting in faded imagery and loss of clarity and detail of the imagery. Compatibility issues can also result in the artwork cracking. These limitations can result in the artworks being deemed unfit for their purpose, particularly when created for exhibition.

This research addressed these limitations through the development of seven print inspired glass processes that alleviated or improved the limitations and provided alternative decorative processes to the use of printed transfers. This was achieved using a multi-method practice led research methodology approached from the perspective of a professional glass artist. To substantiate the research, several bodies of artwork were produced that developed and demonstrated the practicality and creative potential of the creative print inspired glass processes and extended the repertoire of visual effects that can be achieved when decorating blown glass forms.

Throughout the research the print inspired glass processes were assessed for decorative qualities as well as the practicality of each process. To contribute to the limited technical knowledge currently available on the process of combining glass and print for the decoration of blown glass forms, the contextual review consolidated existing information. Technical guides relating to the seven print inspired glassmaking processes were formulated as part of the research.

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V Author Declaration

According to the regulations, I declare that during my research I was not registered for any other degree. Material for this thesis has not been used by me for another academic award.

VI Acknowledgements

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1. Introduction

Chapter 1 considers the rationale for combining printmaking processes and glassmaking processes to decorate glass objects. It describes how in previous practice a number of limitations were encountered when embedding screenprinted transfers into blown glass forms. These limitations define the research questions and contribute to the formulation of the aims of the research. An overview of the research methodology used throughout the research to achieve the aims and objectives is given. Finally the components of work that constitute the research and a summary of the thesis structure are provided. Technical terms used throughout this thesis can be found in the glossary.

1.1 Rationale for combining printmaking processes and glassmaking processes

Combining the two separate disciplines of printmaking and glassmaking is a widely used process in the 21st century and artists have found a myriad of ways to produce decorative artworks. Using printmaking processes in combination with glassmaking processes allows artists to reproduce detailed imagery. At the current time although there is a wealth of information available to artists seeking to combine glassmaking and printmaking, the majority of this information is not specifically related to combining printmaking with blown glass. This has led to a need to research the process from the perspective of a blown glass artist, to bring together conclusions and subsequently develop the findings in an accessible format suitable for use by other blown glass artists.

Printmaking provides a language of marks, a richness of colour and depth and other unique characteristics that cannot be achieved in any other way (Northern Print, 2011). Glass artists are keen to exploit these unique characteristics in their artistic practice to incorporate imagery, pattern and text in the decoration of their artwork. Although decorative artworks date back thousands of years, the decoration of blown glass objects still remains a widely used form of artistic expression. As well as defining age, gender, taste, social rank, beliefs and heritage, decoration can turn a bland object into something more desirable, adding value to the object.

This research focuses upon the development of glassmaking processes for the purpose of decoration as opposed to developing concepts for decoration. It is anticipated that concepts for decoration can be fostered when a sound understanding of the developed print inspired glassmaking processes has been achieved.

In the 21st century printmaking processes used in combination with glassmaking processes are applied across a number of areas of glassmaking. These include flat and architectural glass, kiln-formed glass and blown glass. Direct screenprinting of enamel onto flat glass is a widely used process in the decoration of two-dimensional surfaces. For the decoration of three-dimensional glass forms, imagery can be screenprinted onto special paper known as 'transfer paper' and the transfers subsequently applied to the form. Transfers can also be laser or digitally printed. An alternative method of applying imagery to three-dimensional glass forms involves transferring images from printing plates onto a substrate such as tissue paper. The tissue paper is applied to the glass form and, when pressure is applied, the image is transferred onto the surface of the glass. Although, this process is an ideal way of decorating large areas of glass, care needs to be taken to ensure that the paper does not crease and cause a blemish in the imagery.

A number of recognised glassmaking processes have similar characteristics to printmaking processes. One example includes removing areas of glass to create imagery by sandblasting through a layer of resist. For two-dimensional glass surfaces, imagery can be exposed onto a screen that is subsequently used to print the resist onto the surface of the glass prior to sandblasting. For three-dimensional glass forms, imagery can be exposed onto an ultraviolet light sensitive resist and applied to the surface of the glass prior to sandblasting. Printmaking processes and glassmaking processes can also be combined to produce artworks in which the print and glass are integrated. In this instance the imagery is neither added to the glass nor the glass removed to form the imagery but glass is moulded from a relief or intaglio printing plate prior to kiln-forming (Petrie, 2006).

Although glass and print can be used to decorate both two-dimensional glass surfaces and three-dimensional glass forms, this research specifically focuses on the printmaking processes that can be used with three-dimensional glass forms created through glassblowing. However, it should be noted that a number of two-dimensional approaches using the process of kilnforming emerged at the outset of the research. The glassblowing process used to create the blown glass forms used in previous practice is detailed in Appendix 1.

1.2 Personal background to this research and identification of limitations

Between 2004 and 2008 I produced five bodies of artwork combining blown glass and printed imagery as part of my BA/MA studies and during a Crafts Council Next Move placement in conjunction with the University of Sunderland (See 3.2). This placement enabled me to combine printmaking and glassmaking in the pursuit of artworks and to establish my business Kathryn Wightman Glass. The artworks produced during this period were sold to collectors, submitted to galleries, entered into competitions and selected for exhibitions such as the 2006 International Festival of Glass British Glass Biennale. To me, the interest expressed in this artwork from both the public and other professionals working in the field of glass, confirmed my belief that the visual potential of combining blown glass and printed imagery was a viable process of decoration that warranted further exploration.

Between 2004 and 2008 my usual process of preparing printed imagery for embedding into blown glass forms was through the use of screenprinted transfers. The screenprinted transfer became the vehicle for the imagery that was chosen as the decorative component of each body of artwork. I was able to produce artworks incorporating a diverse range of imagery including figures, pattern, photographic imagery and text. Using screenprinted transfers is an ideal way of transferring imagery to three-dimensional blown glass objects as transfers are flexible and easy to apply to simple glass forms. Transfers can either be digitally printed or hand screenprinted. Four out of the five bodies of artworks I produced incorporated hand screenprinted imagery, the fifth incorporated digitally printed photographic imagery.

To create the screenprinted transfers, high firing enamels were printed onto a special water-soluble paper known as transfer paper. Transfer paper is made up of three layers. Starting from the bottom these layers are; the base paper, a layer of water-soluble gum to enable the image to be separated from the paper after printing and a special thermoplastic top layer known as covercoat. This layer burns off during firing.

As the transfers were to be embedded into layers of blown glass, it was necessary to use high-firing enamels to screenprint the imagery and prevent the images burning out. The transfers were applied by soaking them in water to release the imagery from the backing sheet prior to being transferred to the surface of the blown glass form. The form was subsequently heated to adhere the images to the surface of the glass. To embed the imagery into the glass form additional gathers of molten glass were added.

Despite the advantage screenprinted transfers being easily applied to blown glass forms, I found that there were disadvantages or limitations associated with the process of embedding the transfers. These limitations affected the visual appearance of my artwork and subsequently impacted on my professional practice. Artworks where the limitations were clearly visible were deemed unfit for sale or for exhibition and were discarded. On occasions the artwork did not survive at all or were subject to cracking. This resulted in wasted work and meant that the process was not always cost effective. The limitations that occurred when embedding printed transfers into blown glass forms are defined below:

1. **Stretching and distortion of image** – lateral and longitudinal distortion of imagery beyond recognition resulting in loss of aspect proportion.
2. **Density of image** – loss of thickness and/or consistency of printed imagery resulting in faded areas.
3. **Detail of blown image** – loss of clarity of printed imagery resulting in deterioration of sharpness.
4. **Glass and print compatibility** – depending on the enamel used to produce the printed imagery, compatibility issues arose with unacceptable results e.g. cracking of the glass.

5. **Health and safety** – both water-based screenprinting medium and solvent-based screenprinting medium can be used to produce screenprinted transfers. Solvent-based transfers produced more acceptable results due to the higher enamel/medium ratio but raised health and safety concerns. Health and safety legislation and health implications are important parameters to consider as they limit the level of solvents recommended for use in studio practice.
6. **Lack of information -** there was a notable lack of constructive technical information on embedding printed transfers into blown glass forms.

As well as the disadvantage of the process not always being cost effective, I felt that the above limitations were stifling my creative development as they were affecting the decorative potential of my artwork in that the range of imagery and choice of form that would ensure success was limited. As a glass artist primarily working within an educational environment, I also realised that other glassmakers/students were frustrated by the above limitations when combining screenprinted imagery with blown glass. I felt there was a niche to explore alternative approaches to combining glass and print which could overcome the limitations and offer alternative methods of working, both in my own studio practice and for other glassmakers.

This led to the formulation of the following questions:

1. Can the limitations encountered when embedding screenprinted transfers into blown glass forms be clarified and documented?
2. Is there evidence that limitations have been experienced by other artists working with glass and print?
3. Are there any creative print inspired glass processes that can be successfully adapted to combine glassmaking and printmaking?
4. Could these creative print inspired glass processes overcome any of the documented limitations?
5. Could additional technologies such as water-jet cutting, stencil cutting and laser cutting improve the creative print inspired glass processes?

6. What new routes in terms of visual qualities might the creative print inspired glass processes offer the blown glass artist in the development of decoration?

1.3 Aims of this research

These questions led to the development of the aims of this research:

1. To clarify and visually document the limitations encountered when embedding screenprinted transfers into blown glass forms through a series of practical examples.
2. To develop and document creative processes of working with glass by drawing inspiration from existing printmaking processes and adapting them for use in the decoration of blown glass forms.
3. To extend and demonstrate the decorative potential of creative print inspired glass processes as possible models for other practitioners combining blown glass and print.

1.4 Overview of methods used to address aims of this research

This research is a multi-method practice-based study where practice was used as the 'interrogative' process (Durling, Friedman and Guntherson, 2002). Practice-based research can be divided into three categories – research into practice, research through practice and research for the purpose of practice. Research into practice refers to research where art or design practice is the object of the study. Research through practice refers to research where art or design practice is the vehicle for the research and a means to communicate the result. Research for the purpose of practice aims to communicate the research embodied in a piece of artwork (Frayling, 1993). This research is primarily research through practice where the artwork produced throughout the research is the vehicle for knowledge gained from the research. The final artworks visually communicate the knowledge gained from the research to other artists interested in combining the two separate disciplines of glassmaking and printmaking in studio practice. A review of research methods used in other practice-based doctoral research studies was undertaken to compare and contrast methodological approaches. Twenty-four completed and ongoing Ph.D. research degrees were compared (Appendix 2).

Seven of the twenty-four theses were related to glass with the remaining sixteen being related to ceramics. Similar to my own research, the majority of researchers undertook studio experimentation and testing of new processes. Three of the researchers used case studies to highlight relevant artists but only two researchers documented peer contact. Twenty of the researchers submitted their thesis in the form of illustrated written text. One researcher submitted their thesis in the form of a video and three researchers used a CD Rom. Fifteen researchers presented a range of artworks for reference at the examination whilst a further six researchers presented their test pieces to substantiate their research. Four researchers staged a final exhibition. One researcher presented knowledge gained through a publication.

In summary, the methodology used in this research study was descriptive case studies of relevant artists and their artworks using textual descriptions and visual analysis with photographs. Critical analysis was undertaken during the observation of my previous artwork in order to apply a further level of thinking about what had occurred before. This involved questioning, evaluating, making judgements and finding connections. Contact with artists who combine printed transfers with blown glass clarified whether they had encountered similar limitations to my own practice. Technical guides were developed to document the creative print inspired processes for other artists. A written thesis in the form of illustrated written text detailed the research. Artworks were produced to demonstrate the creative print inspired processes. These artworks were used as part of an exhibition at the National Glass Centre in Sunderland.

Initially the literature was searched for key artists who had embedded printed transfers into blown glass forms. Although the information on artists who use this particular process was limited, six artists were identified (See 2.2). These artists were considered to be relevant as their process was similar to my previous process of embedding printed transfers into blown glass forms. Each of the six artists combined printed transfers with blown glass by either applying the transfer to the surface of the blown glass form or they embedded it into layers of hot glass. The process that they used and the artworks they produced were documented in the form of descriptive case studies (See 2.2).

Each case study contained an image of the artwork created using printed transfers together with a brief description of the process they used to create the artwork. The concept behind the artwork was explained as this contributed to the overall decorative appearance of the artwork. Where possible, the artists were contacted via email with a series of questions regarding their process, including direct questions about any limitations they had experienced when embedding their printed transfers. This information was not always evident from available literature. The purpose of communicating with the six key artists was to validate my research and confirm that other artists had experienced limitations when combining blown glass and print. This addressed research question 2 – Is there evidence that limitations have been experienced by other artists working with blown glass and print?

Information on artists who combine glass and print in artistic practice or who have undertaken specific research on this process was sought from a variety of sources. To identify existing research into combining the two separate processes of glassmaking and printmaking, completed and ongoing Ph.D. theses were accessed via Index to Thesis using an advanced Boolean search. The key terms used to search the literature were 'hot glass and/or print, glass and/or print, blown glass and/or print, glass and/or narrative, screenprinted transfers, screenprinting and/or glass, printmaking, printmaking and/or glass, glass and/or surface decoration, screenprinted decals, technology and/or printmaking, technology and/or glass, surface decoration/transfer printing, transfer printing and/or glass'. These terms were chosen because they covered the main aspects of the research. The term 'screenprinting' was searched as both one word and two separate words. Phrases were used as using one-word terms yielded a large number of results, all of which were inappropriate to this study. Relevant Ph.D theses identified are discussed in 2.1.

The British Library's electronic table of contents targeted journal articles and conferences relating to glass and print. It was accessed using the relevant key terms in a general search.

Relevant journal articles and conferences found during this search are discussed in 2.1. The online public access catalogue (OPAC) was accessed using the key terms and a title search to identify relevant publications.

Information on artists who use the process of embedding screenprinted imagery into blown glass forms for the purpose of decoration was limited. It was, therefore, considered informative to consider the work of artists who use other printmaking processes adapted for glass as a means of decoration (See 2.3). Retrospective analysis involved comparing and contrasting the visual qualities of artists who removed areas of glass to form the decoration, artists who added elements to create the decoration and artists who decorated glass that was subsequently used to create the form. (See Table 1). The practical advantages and disadvantages of using these processes are outlined in Table 2. Table 3 focuses on how the limitations described in 1.2 might affect artworks created using these processes.

One research methodology deemed appropriate for this practice-based research was the reflective process. This involved retrospective analysis of the five bodies of artwork I produced between 2004 and 2008 (See 3.1). This was to clarify whether the documented limitations were visible and if so whether they detracted from the decorative appearance of the artwork. The rationale for the retrospective analysis of my own artwork was to utilise my in-depth knowledge of how the imagery appeared 'pre' as well as 'post' firing. Analysing the artwork of other artists who combine glass and print would not have enabled me to compare the imagery in this way as I had no knowledge of their imagery pre-firing. Retrospective analysis involved assessing the printed imagery in the context of the limitations and recording the results using explanatory text and visual photographs. Strategies that had been employed to disguise the limitations of stretch, distortion, loss of density and loss of detail were identified and recorded (See 3.2). At the onset of this research I perceived that the limitations were stifling my creative development and potentially limiting the decorative potential in my artwork.

Retrospective analysis of my previous bodies of artwork helped to explain these perceptions by clarifying whether the imagery in each of the artworks had been chosen with the limitations in mind. Retrospective analysis of my previous artworks confirmed that the limitations had often been disguised. Therefore, to ensure clarity, it was felt necessary to undertake a series of demonstrations where the limitations were clearly visible. This addressed aim 1 of the research – To visually demonstrate and document the limitations encountered when embedding screenprinted transfers into blown glass forms.

The demonstrations were undertaken by screenprinting a standardised image specifically designed for the demonstration and which included a number of specific decorative components (See 3.3). Horizontal/vertical lines, pattern, dense areas of colour, various sized text and a universally recognized figure were all included in the standardised image (See Figure 41). Rather than being integrated within a more complex image, the standardised image was a simple image with each component clearly visible so it could be assessed individually. The screenprinted transfer with the standardised imagery was produced in accordance with my previous practice (See 3.4). The screenprinted transfer was applied to two pre-blown glass forms (See 3.5).

The first form was used to demonstrate how each component in the standardised image was affected when it was simply embedded into a layer of molten glass. The second form was used to demonstrate how each component in the standardised image was affected when the screenprinted transfer was embedded into a layer of molten glass and the form was inflated during the blowing process (See Figure 42). This documentation with photographs and explanatory text was useful to me as it clarified the limitations and provided a basis for the latter aspects of the research.

Retrospective analysis was used to examine each component for stretch, distortion, loss of detail and loss of density and a decision was made on whether the image was 'acceptable' or 'unacceptable' for use in professional practice. For clarity, the results are presented in the form of a table (See Table 4 and Table 5).

The photographic evidence is an additional visual record of how screenprinted transfers are affected when embedded into blown glass forms and inflated during the blowing process and it is a useful technical record for other practitioners. One possible bias in documenting and recording the limitations in this way is that there is no formal definition for the terms ‘acceptable’ or ‘unacceptable’. The decision to use these particular terms was based on my own opinion and standards developed as a professional glass artist.

The next step in the research was to explore alternative processes that could potentially overcome the limitations. Various printmaking processes were explored to assess whether they could be adapted into a glassmaking process for integration into blown glass forms as a means of decoration. This met aim 2 of the research – To develop and document creative processes of working with glass by drawing inspiration from existing printmaking processes and adapting them for use in the decoration of blown glass forms. In order to identify suitable printmaking processes that could be adapted, information into printmaking (See Appendix 3) was sought from existing literature as well as from collaboration with both the Glass and Ceramics Department and the Printmaking Department at the University of Sunderland.

It was then possible to undertake practical trial and error experimentation within a studio environment considering cause and effect (See Chapter 4). A standard format for recording each experiment was adopted in order to structure the experimentation and maintain logical documentation. The background to the printmaking process was identified and open questions formulated to direct the initial stages of the experiment. A cause and effect hypothesis was developed in relation to each question. A technical guide with photographs and explanatory text was provided for each experiment. One advantage of this initial experimentation was that it allowed controllable variables for each creative process to be determined (See 3.7). These controllable variables were essential during the making of final artworks to substantiate the creative print inspired processes.

Five printmaking processes were adapted for use with glassmaking processes. In the initial stage the creative processes were designed to decorate two-dimensional glass surfaces. To create a three-dimensional form from these two-dimensional sheets, it was felt that 'roll-up' was the most appropriate glassmaking process to facilitate this. The roll-up process ensures there is minimal stretch and distortion. Scott Chaseling is an Australian who developed the roll-up process together with Kirstie Rea (See 2.2.3). The finished artworks using the roll-up process were photographed to provide a visual reference. Written analysis highlighted the advantages and disadvantages of each creative print inspired glass process and indicated whether any of the documented limitations could potentially be overcome by using this process.

Finally it was possible to utilise the most successful creative processes in terms of practicality and decorative potential to produce final bodies of artwork (See Chapter 5) where the artwork was the vehicle for the knowledge gained throughout the research – research through practice. The final artworks were photographed. These artworks demonstrate the creative potential of each successful print inspired glass process. This met aim 3 of the research – To demonstrate the decorative potential of creative print inspired glass processes as models for other practitioners working in the field of blown glass and print. The rationale behind each body of artwork is given and a technical guide provides information on how each creative print inspired process could be used as a means of decoration. The technical guides include parameters such as firing cycles and will be of use to other artists interested in using the creative print inspired processes in their own practice. Details of how the artworks were integrated into my own professional studio practice are provided. This involved identifying the visual decorative qualities of each of the nine artworks and comparing and contrasting them to the visual qualities produced by other artists documented in chapter 2. These artists used a range of glassmaking processes to decorative blown glass forms.

1.5 Objectives of this research

The objectives developed relate to each of the corresponding aims detailed in 1.3:

1. To visually demonstrate the defined limitations when embedding screenprinted transfers in to blown glass forms.
2. To identify and test a range of printmaking processes for their adaptability to the medium of blown glass.
3. To create a body of artwork using the creative print inspired processes of combining the two separate disciplines of glassmaking and printmaking.

1.6 Components of work that constitute this research

1. A range of artworks were created using creative print inspired processes; presented for reference at examination and documented in the thesis through photographic illustrations.
2. A written thesis outlining and describing the principles of the research and work undertaken.

1.7 Summary of thesis structure

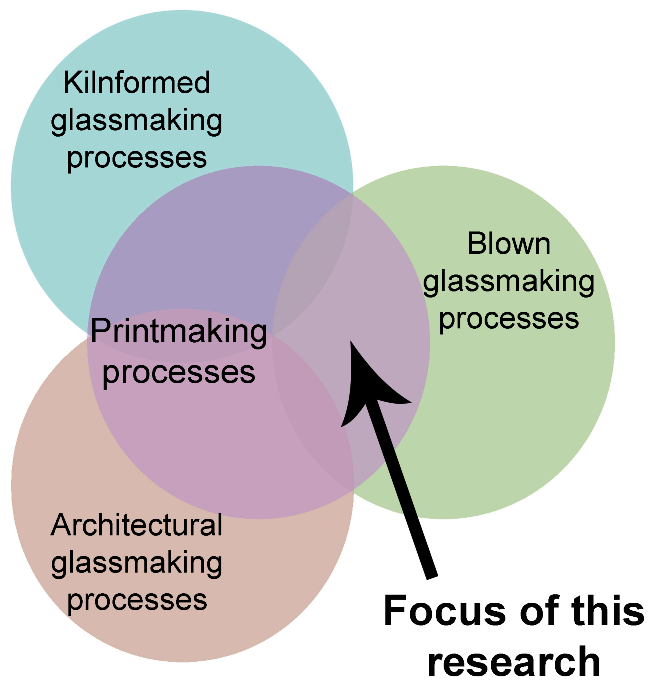
- Chapter 1 introduces the research problems and identifies the aims and objectives.
- Chapter 2 documents the current field of hot glass and print. It also introduces other processes that are widely used to decorate blown glass.
- Chapter 3 documents the limitations encountered when embedding screenprinted transfers into blown glass forms.
- Chapter 4 documents the creative processes that overcome the technical problems associated with the documented limitations of combining glassmaking and printmaking and contribute to the decorative potential of artwork.
- Chapter 5 documents the making of artworks produced throughout this research. This validates the use of creative print inspired processes for combining blown glass and print from the perspective of a professional artist working with the medium of glass.

- Chapter 6 discusses the findings of the research in relation to the questions, aims and objectives identified in chapter 1. It also identifies areas for further research.

2. Contextual Review

Chapter 2 creates reference points to position the research in the field of blown glass and print. It begins by identifying relevant literature relating to blown glass and print and documents contemporary practitioners who apply/embed printed transfers onto/into blown glass forms. Alternative decorative processes that relate to printmaking and blown glass are identified and discussed. The artworks created by practitioners using these processes are compared and contrasted to evaluate the different visual effects that each process can achieve. Finally a conclusion draws the information together.

2.1 Literature relating to the field of blown glass and print



The above diagram represents the wider context of glassmaking used in combination with printmaking. The green circle represents printmaking processes whilst the pink, purple and blue circles represent the glassmaking processes of architectural glass, blown glass and kilnformed glass. The three overlapping sections show how only a small section of each glassmaking process is relevant for combination with printmaking processes. This research will focus on the overlap between printmaking and blown glassmaking as this is my area of interest and expertise.

In order to identify past and present developments in the field of blown glass and print, the initial section of the contextual review involved searching for literature on integrating blown glass and printmaking in artistic practice. Ongoing and completed Ph.D. research studies, journal articles, publications and conferences were searched for relevant information.

Although four relevant theses were identified from searching the Index to Thesis (ASLIB and BIDS) using the key descriptors listed (See 1.4), none were specifically related to my particular research area of blown glass and print. The technical information on printmaking found in the four relevant theses provided general information on printmaking processes. Hamilton (2006) discussed the possibility of harnessing technological advancements in creative practice. This was relevant as one of the research questions addressed the use of technology in novel print inspired glass processes. Pengelly (1997) and Challis and Roberts (1990) both addressed health and safety issues, an important consideration for a glassmaker working in an educational environment. Petrie (1999) focused on aspects of health and safety in relation to ceramic transfer printing, namely the development of water-based transfer printing. Aspects of Petrie's approach were valuable to this research as elements of his documented process of printing water-based transfers were utilised when embedding screenprinted transfers into blown glass forms.

Two relevant publications were initially identified from searching the Online Public Access Catalogue (OPAC). Petrie's (2006) handbook offers a range of processes that can be used by glassmakers, as well as informative case studies on artists who combine glassmaking with printmaking processes. It gives instructions on specific processes relating to glass and print and includes a section on blown glass and print. Petrie did not include details of printing on to three-dimensional forms in his publication although Ramsden (1971) did discuss direct printing on to glass. A further publication by Bray was subsequently identified. This was relevant to this research as it described the process of applying screenprinted transfers to blown glass forms (Bray 2003) and confirmed that my previous practice of using screenprinted transfers was a recognised and documented process.

A very recent publication 'Ceramic Transfer Printing' has emerged. This publication is primarily about integrating printmaking processes with ceramics but it does have similarities with my own research and includes a section detailing current practitioners combining glass and print (Petrie 2011).

From searching the British Library's electronic table of contents (ZETOC), relevant journal articles and conferences were identified. The articles identified primarily gave information about printmaking and only two of the articles were related to blown glass and print. The first article identified practicing artists using relevant processes (Petrie, 2006) and the information found in this publication was useful in defining the key artists (See 2.2). In the second article Shelley James (2010) described her work where digital transfers were integrated with hot glass. James's research was carried out at the University of Creative Arts, Farnham and the Centre for Fine Print at the University of the West of England. She had also collaborated with two UK digital print suppliers, Fotoceramic and Digital Ceramic Systems. James states that, despite the advantages digital transfer printing offers in comparison to traditional screenprinting methods, few artists are working with the process.

James' states that the advantages of digital transfer printing includes the low cost of using the process, the ability to produce fine detail or small-scale work as well as the small amount of raw material required. However, James also recognised that the amount of colour used in each print was tiny and could not compete with the density of traditional screenprinted imagery. James's research gave insights into the production of digital transfers, it identified and explained the purpose of the four layers used to make up a digital transfer; the special backing paper, the water-based releasing agent similar to gum arabic, the image which is made up of tiny dots of toner and the final layer of covercoat or sealer. James discussed different variations in the transfers produced and gave examples of possible situations in which the different transfers could be used.

A conference in October 2006 organised by the Institute for International Research Group (IIRG), University of Sunderland and staged at the Royal College of Art highlights the emerging interest in combining printmaking with contemporary glass practice (Glass and Print Symposium, 2006).

The conference included five practitioner presentations, discussed historical precedents and considered new technical research in the field of glass and print. Per B Sundberg discussed hot glass and the printed image (no transcript). Martin Harrison's presentation gave insights into the history of print and photography used in stained glass. Steve Brown described a novel screenprinting process that he had adapted for use with kiln-formed powdered glass. Andrew Moor considered flat surfaces of glass and the application of enamels and screenprinting as well as the application of films. Petrie brought together a number of perspectives to take a focused view of the field of glass and print. He discussed current glass and print processes used by artists across the three main areas of glassmaking. Out of the nineteen artists mentioned in Petrie's presentation, only five artists used blown glass in combination with printed transfers. One of the artists used blown glass in combination with sandblast resists. The conference coincided with the publication of the handbook Glass and Print (Petrie, 2006), which is further evidence on the emerging interest of combining glass and print.

One of the speakers at the conference, Steve Brown (a former textile printer) has undertaken a collaborative Ph.D. research study investigating the physicality of printmaking with the Royal College of Art and the Victoria and Albert Museum. In his research he has developed a process that involves a more integrated relationship between printmaking and the manipulation of clay. Brown focuses on the relationship and balance between image and form, an important consideration in my own research. Brown has also experimented with combining aspects of screenprinting with glass powders. He recognised parallels between glassmaking and printmaking processes and he subsequently explored these parallels at the Bullseye Glass Company, USA in 2005. Developments involved dusting glass powder on to a glass sheet through a coarse mesh screen stenciled with vinyl graphics that was then fused together in a kiln. Successful artworks culminated in the exhibition 'Printmakers Fired' at the Bullseye Connections Gallery, USA in 2005 where local and international printmakers explored the possibilities of working in glass. Brown developed this process further whilst at University of Sunderland by removing the glass sheet to which the image was applied.

Brown states that this process shares similarities to stereo lithography, a process used in the field of rapid prototyping. Aspects of Brown's process have been utilised in my research (See section 4.2).

Although various sources were accessed and some useful information was obtained, this contextual review confirmed that technical information on the specific process of combining glass and print was limited. Although I found this disappointing, it was not surprising as it had been a consistent finding in previous practice. Lack of information on contemporary glassmaking processes was also documented in available literature. Cowie (2002) recorded that there was a lack of technical documentation on contemporary glassmaking processes in Australia.

Her MA thesis completed in 2002 entitled 'World Glass: A Glass-Makers Perspective, documented that the majority of text-based knowledge about studio glassmaking in Australia was from a visual arts or crafts historic viewpoint. Cowie noted that information was often from the perspective of a historian, theorist or a non-glassmaker as opposed to an expert in the field. It is, therefore, not surprising that third party information often used to describe artists and their work, lacks useful technical data from a glassmaking perspective.

During the literature search it was evident that in many cases information on a particular artist or the specific processes they had used to create their artwork, was primarily to promote the artist or to accompany an event/exhibition that the artist was involved in. The author produced a visual exemplar of the artwork and elaborately described the decorative potential and the inspiration behind it. The information commonly bypassed the technical processes used to produce the artwork or it simply give a short synopsis of the processes in the form of a title. Not divulging processes inevitably maintains an air of secrecy. This is a strategy that has been adopted throughout history and reticence to disclose glassmaking techniques is a recurring trait. Historically the special skills of glassmakers were passed from father to son and were a highly guarded secret. A documented example of keeping techniques and technologies in glassmaking a secret was found on the Island of Murano in Italy.

In the 10th century glassmakers moved from the mainland to the Island of Murano and set up a community devoted to glassmaking. Many new techniques originated in this community. The glassmakers were forbidden to divulge these techniques to the extent that they were not allowed to leave the island and the penalty for revealing secrets was death. The island of Murano led the field in glassmaking for several centuries (Murano Italian Glasswork, 2010).

In a similar way to the glassmakers on the Island of Murano, many glassmakers are not keen to detail their individual processes that contribute to the success of their studio practice as this is what gives their artwork an element of individuality. Artists are often recognised for their individual approaches and many prestigious exhibitions are subject to artist selection, often by a jury who are looking for distinctive and innovate artwork. A unique style is often the artist's trademark and uniqueness can contribute to why people buy a particular artist's work, promoting the reputation and status of the artist.

The status of an artist is often the artist's brand. Jonathan Schroeder (2005, pp.1291-1305) cited in his research that successful artists can be thought of as brand managers, actively engaged in developing, nurturing and promoting themselves as recognisable products in the competitive cultural sphere.

2.2 Practitioners who use printed transfers to decorate blown glass forms

The second part of the literature review focused on the six main artists identified in the literature who apply screenprinted, commercially produced or digitally printed transfers to blown glass forms. The following six artists were the only artists identified at the time who were exploiting the use of these two processes. Where possible the artists were contacted via email with a series of questions regarding their process including direct questions about any limitations they had experienced when embedding their printed transfers.

Figure 1 **Per B Sundberg** 'Fabula' 2000. Blown glass with printed transfers

In the artwork 'Fabula' (Figure 1), Per B Sundberg (1964) from Sweden, embedded commercially printed ceramic enamel transfers into layers of blown glass. He chose an organic form to display his pictorial imagery to its best advantage. Sundberg produced this artwork in 1997 whilst working at Orrefors, one of the world's leading glass manufacturers. Sundberg states that the 'Fabula' process involves firing the printed transfers onto the parison and during the blowing process overlaying it with a thick layer of glass (Scandinavian Design, 2003). An example of Sundberg's 'Fabula'collection is on display at the Victoria and Albert Museum, London. The artwork entitled 'Fabula: Animal Face' consists of an irregular hollow form in clear glass, with images of dogs, cats and horses inside the glass. Fabula was inspired by a tale of creatures and ghosts in a world where anything could appear (Glass Art Society Journal, 2007).

Figure 2 Cathrine Maske 'Blue Wing Vase' 2007. Blown glass with screenprinted transfers

In 'Blue Wing Vase' (Figure 2), Cathrine Maske from Norway, used the process of embedding screenprinted photographic imagery into a blown glass vase. The work was produced in 2004 and is part of the 'Libelle Series' (Petrie, 2006). Screenprinted transfers of endangered dragonflies were embedded into thick layers of glass and subsequently blown into a simple 'vase'. The vessel form was deliberately simple to intensify the lens like effect and give the feel of looking through a microscope at the preserved creatures.

Maske often exploits the optical properties of glass in her artwork. Depending on the angle at which ‘Blue Wing Vase’ is viewed, surprising optical effects contribute to the decorative appearance of the artwork. The dragonflies are from a collection on display in the Natural History Museum in Oslo.

Figure 3 **Amy Reuffert** ‘Curios’ 2007. Blown glass with commercially produced ceramic transfers

Amy Reuffert (1972) is an American artist who embeds commercially produced transfers into layers of blown glass. In her work both the transfers and the glass play an equally important role. Reuffert states in her biography that the optical qualities of the glass allow her viewers to focus on the vintage ceramic transfers she favors, chosen to evoke a feeling of nostalgia (Reuffert, 2007). ‘Curios’ (Figure 3) is a typical example of the commercially printed transfers that Reuffert uses in her artwork. In an email conversation (August 2010), Rueffert described how she began to experiment with combining printed transfers with fused glass whilst working with ceramic transfers at graduate school. She subsequently experimented with printing her own transfers using a laser printer and water-slide transfer paper.

Reuffert also used her own images that were commercially printed in full colour. When specifically asked if she had encountered any of my defined limitations (stretching of image, fading of image and distortion of image) when embedding her printed transfers into blown glass forms, she confirmed she had experienced issues with all of them. Reuffert described the problems she had experienced with certain colours burning out, hot spots appearing whilst blowing and crazing and bubbling issues. The strategy she currently uses to overcome the above limitations is to test each transfer to see if it will be problematic. She then avoids using that specific transfer or using tacit knowledge she adjusts her process in the hot shop, for example making the blown object thicker.

Rueffert states that she currently uses printed transfers in her work because she favours the richness of the images in both content and color and the transformation of these images in combination with the optics of glass. This information was useful as it confirmed that other artists had experienced similar limitations to my own. Although the images Rueffert uses are a significant part of the decorative element of her work, she also feels that the form she chooses to complement the imagery is of equal importance. Embedding the transfers between layers of glass is important to her because of the optical quality and the visual and conceptual value the layers add to the artwork. Rueffert informed me that she has not yet considered combining glass with any other form of printmaking process in her artwork.

Figure 4 Shelley James **'**Eckmen II' 2005.
Blown glass with hand screenprinted transfers

Shelley James is a British artist whose M.Phil work seeks to explore the immense expressive potential of combining printmaking with glassmaking. Although now working with blown glass, James has a background in textiles with an MA in printmaking. An example of her work is 'Eckmen II' (Figure 4) in which surreal hand printed 'eye' transfers are embedded into layers of blown glass.

There is a strong narrative element in James's artwork that deals with the theory that signals conveyed by the eye and mouth (such as happiness, sadness, fear, surprise, contempt, disgust and anger) are universal traits. To create this artwork, hand screenprinted transfers were applied to a clear glass bubble. The bubble was reheated and a gather of hot glass used to embed the imagery. The glass form was allowed to cool and another set of transfers applied before reheating, gathering, shaping and polishing (James, 2005).

Figure 5 Jeffrey Sarmiento 'Fighter' 2007. 130 cm x82 cm x 5 cm. Blown and enameled glass

Jeffrey Sarmiento (1974) is a Filipino-American glass artist who uses a complex range of printed imagery in his artwork. He has explored many processes of combining glass and print. In 2007 Sarmiento produced an artwork entitled 'Fighter' (Figure 5) using digitally printed transfers fired onto blown glass plates as opposed to embedding them into layers of blown glass. In an email conversation, Sarmiento told me that his first attempts at transferring images to glass was in 2000. He used Liquid Light emulsion and a darkroom exposure unit to place his images on to solid worked glass objects. In this case the imagery may not have been considered to be permanent. Sarmiento's first experience of using printed transfers was during a residency at Wheaton Arts in 2002. The artwork he created incorporated solvent-based transfers printed with Paradise paint and then covercoated.

Figure 6 Marie Retpen 'Still Life Meltdown' 2008. 25 cm x 15 cm x 15 cm. Glass with ceramic transfers

Marie Retpen (1978) is an artist and designer from Denmark. Her signature style is crumpled vases. In her work, evoking a sensation, telling a story and interacting with her audience is important (Retpen, 2009). In 'Still Life Meltdown' (Figure 6), Retpen applied printed transfers to the surface of a blown glass form. Although the printed imagery is not embedded into the layers of glass, the fact that the pattern follows the contours of the crumpled form implies that further hot manipulation, either through blowing or kiln-forming, was subsequently undertaken. It would not have been possible to apply a printed transfer to this complex form without creasing and splitting occurring.

The artworks of these six artists demonstrate the diverse range of decorative effects that can be obtained through both embedding printed transfers into layers of blown glass forms or firing printed transfers directly onto the surface of blown glass forms. A common thread was the use of the printed transfer to produce artwork that documented a period in time, recorded an event, or conveyed a message to their audience. All the artworks aimed to evoke some form of response from the audience.

The printed imagery in all of the artworks was an important part of the decorative appearance although it was the integration of the imagery with the three-dimensional glass form that ultimately created the unique artwork. If the printed imagery had simply been placed on a two-dimensional sheet of glass, the visual effect would have been completely different. The result in all these artworks was that the imagery not only complemented the form but the form complemented the imagery.

When considering the three-dimensional glass forms that these six key artists used to display their printed imagery, cylindrical, conical and spherical forms were often part of their repertoire. Using a simple three-dimensional form is a good choice for the artist who wants to give the viewer immediate access to the printed imagery rather than having to understand and interpret the form first.

This element can be demonstrated in Maske's artwork where, because of the simplicity of the form, the viewer has immediate access to the preserved insects. In contrast Sundberg, chose a more complex form to present his printed imagery but he exploited the optical distortion of a thick casing of glass that was intentionally manipulated after the imagery had been embedded. In this artwork the viewer would need look into the form before grasping the concept behind the printed imagery.

From the six artworks reviewed, four of the artists chose to embed their printed imagery into layers of blown glass, the other two artists applied the printed imagery after the form had been blown. Embedding printed imagery into layers of blown glass can add a new dimension to the artwork as it can give the work a completely different appearance. Rhodes (Oldknow, 2008, p.28) states that things can happen in different layers of glass that can make it completely three-dimensional and atmospheric, changing the overall visual effect.

Embedding imagery into layers of glass exploits the optical qualities of the medium and it can also prolong the life of the imagery. It is recorded in the glass collection at the Sunderland Museum that there are limited examples of work combining printed imagery as it tends to crack and fade. Rhodes expresses the view that colour trapped in glass never fades.

In the six artworks documented, each artist adopted their own particular style when placing imagery on to their chosen form. The concept behind the artwork often contributed to the style chosen when deciding on the placement of the printed imagery. Sundberg adopted a collage style approach where various sized, coloured tonal images were overlapped. Although the placement of the printed transfers in Sundberg's work may have appeared to be a random pattern, the images were in fact strategically placed to create a particular effect where the viewer did not know what would appear in the next image. Maske placed her imagery evenly across the form with all the images pointing in the same direction. This ensured that the imagery was easily understood. Rueffert used a patchwork style to assemble coloured transfers that combined patterned and figural imagery. James also adopted a collage style approach when placing her representational printed imagery, using layers of imagery to add depth to the artwork.

Sarmiento took a different approach; instead of using multiple images on one glass form, he used multiple blown glass plates to create one large pictorial image. Each glass plate carrying one section of the overall image was overlapped to build up a complete picture. Retpen's approach consisted of placing all-over patterned printed imagery to entirely cover her blown glass form.

These different styles and approaches demonstrate the variety of imagery that can be produced and the decorative potential that can be achieved when combining printed transfers with blown glass.

2.3 Alternative glassmaking processes sharing similarities with printmaking processes used to decorate blown glass forms

As there was limited information on artists who specifically embed printed transfers into blown glass forms, it was felt it would be useful to compare and contrast artworks from artists who use other glassmaking processes with shared similarities to printmaking processes for the purpose of decoration. This was to establish how the visual qualities achieved through the use of printed transfers compared to the visual qualities in other processes used in the decoration of blown glass. The history of glass decoration, including processes, styles and trends are documented in Appendix 4.

The specific processes documented below can all be used to decorate blown glass forms although some of them bear more of a relationship with printmaking than others.

The glass decoration processes were divided into three groups:

- Removal of areas of glass from the form to create decoration (See 2.3.1)
- Addition of elements to the form to create decoration (See 2.3.2)
- Decoration made from glass that is subsequently used to create the form (See 2.3.3)

2.3.1 Removing areas of glass to create decoration

Typically in relief and intaglio printmaking, areas of a matrix are removed to create the plate from which the image is printed. Depending on the type of plate being used, various processes can be undertaken to remove areas and create the printable surface. Printmaking removal methods include scratching, cutting, engraving and etching. There is a direct link between some of these printmaking processes of removal and processes that are used to remove areas of glass in the decoration of blown glass forms. Processes of removal specific to glass include engraving, etching, sandblasting. One difference in how these processes are used in each discipline, is that in printmaking the final artwork takes the form of a print from a plate, that has had areas removed. In glassmaking the areas removed are part of the surface of the glass forming the artwork.

Another difference is that in printmaking it is typically a two-dimensional surface from which the areas are removed compared to glassmaking where the surface from which areas are removed is often three-dimensional. The information below relates to the glassmaking processes of engraving, etching and sandblasting. Engraving is the process of cutting into a glass surface. Processes of engraving include copper wheel engraving, intaglio work and diamond or tungsten point engraving (Bray, 2001). Artists who engrave blown glass forms to create decoration can achieve a diverse range of decorative effects. The following information demonstrates the diverse range of visual effects that can be achieved by artists who remove areas of glass to create decoration. An evaluation which makes reference to each of the artists featured can be found in 2.4.

Figure 7 Katharine Coleman 'Small Broken China Bowls III' 2010. 13.5 cm x 14.5 cm Blue overlaid clear crystal bowl cut, polished, drill and wheel engraved.

Katharine Coleman (1949) is a glass engraver who was taught point, drill and copper wheel engraving on glass by Peter Dreiser, an expert engraver. She engraves onto clear lead crystal blown glass forms that are overlaid with a thin skin of coloured glass. 'Small Broken China Bowls III' (Figure 7) is a typical example of her instantly recognised artwork. Her work requires close collaboration with other artists who blow the glass. After annealing, the top surface of the glass is cut, ground and polished so that when the subsequent engravings on the outside surface are viewed, it is possible to see inside the piece. All the refractions on the outside are repeated on the inner surface, creating an illusion of one body floating inside another. Coleman uses traditional techniques, engraving the glass surface with lathe-mounted copper, diamond and stone wheels, to create a crisp and fine finish. The inspiration for her work ranges widely from natural history to the modern urban landscape (Coleman, 2010).

Figure 8 Ronald Penell ‘Falling and Diving’ 2003. 7" x 6 .5" Green over cased glass, engraved.

Ronald Penell’s (1952) engravings take an ironic and slightly humorous view of human conditions based upon events taken from English country life or European and world myths. He engraves directly onto glass using a fixed head lathe and diamond wheels; the designs evolve spontaneously without reference to prior drawings (Penell, 2009). ‘Falling and Diving’ (Figure 8) demonstrates the humour often found in Penell’s work.

Figure 9 Helen Millard ‘River Bank Scene’ 2006. 22 cm high. Cameo vase sandblasted through the surface in sections, acid dipped and diamond engraved.

Helen Millard uses a process developed from Cameo art glass. Coloured glass is surface engraved to depict her fascination and love of nature. Every item is hand blown. Millard states that it takes up to 50 hours to engrave her artwork. ‘River Bank Scene’ (Figure 9) has an inside coloured casing of light aqua blue and an outside coloured casing of dark blue, green and amethyst. The vase has been sandblasted through the surface in sections, acid dipped and diamond engraved. It depicts a riverbank scene with a dragonfly and frog (Millard, 2008).

Figure 10 Ethan Stern 'Vexilla' 2007. 50 cm x 27.5 cm x 10 cm. Blown and carved glass.

Ethan Stern (1978) moved from ceramics onto glass. His work is concerned with the idea of simplicity and the abstract form that is overlapped by surface pattern and texture. He has investigated engraving and carving glass, processes that have allowed him to pull together elements of color, form, pattern and texture. In 'Vexilla' (Figure 10) Stern has removed the glossy shine of the glass and he allows the viewer to focus on the surface color and design rather than the material. The patterns he creates can be repetitive and often reminiscent of ethnographic textile design but his personal mark is apparent. His cutting can create a linear quality that can be graphic or painterly. Evidence of the hand, the subtleties of surface and the creative process are vital to the creation of Stern's work (Stern, 2007).

Figure 11 Dominic Fonde '**Fear of Ghosts' 2006. 16 cm diam. Blown and engraved bowl

Dominic Fonde (1974) is a glassblower and writer whose work is influenced by his observations of the everyday world, nature, music, and the physical process of glass making and the other media he uses. In his artwork, Fonde integrates glass forms with the written and spoken word through the engraving of stories onto the surface of the glass (Fonde, 2008). 'Fear of Ghosts' (Figure 11) is a typical example of his stories engraved onto a blown glass forms.

Etching is a process that can be used to create shiny, matt or frosted areas of glass. The process of etching involves controlled exposure of the surface of the glass with hydrofluoric acid derivatives. To produce decorative etching, resists or stencils are applied to the surface of the glass prior to the application of acid. One method of applying a resist to a three-dimensional form involves dipping the form into the molten resist material. Once the resist has set, areas can be scraped away to expose the surface of glass to be etched. (Bray, 2001). Acid etching is not widely used in studio practice because acid is both toxic and corrosive and stringent safety precautions are mandatory when using this process. Sandblasting is an alternative, more widely used process that can be used to frost the surface of glass. Sandblasting is carried out in a cabinet with built in extraction facilities. It involves pressurized air being released into a container holding an abrasive that accelerates it through the nozzle of an air gun onto the glass. Decorative sandblasting involves the application of some form of resist to the surface of the glass to mask off the areas not to be sandblasted. Types of resist include masking tape, Fablon and polyvinyl acetate etc (Bray, 2003). The following information demonstrates the diverse range of visual effects that can be achieved by artists who sandblast blown glass forms to create decoration.

Figure 12 Gillies Jones 'Aesculus Blue Over White' 2005. 19 cm x 26 cm. Two colour blown glass vessel with sand carved detail

Gillies Jones is a partnership between Stephen Gillies (1967) and Kate Jones (1966). Drawing inspiration from the beauty of their rural surroundings, their artwork has a unique visual quality, evident in 'Aesculus Blue Over White' (Figure 12). Gillies is a glassmaker and he blows the hot glass forms. Jones has moved from painting through to printmaking and then to glass and she is responsible for the sandblasting stage. Their work aims to highlight connections, patterns, and symmetry, the sacred in nature and our undeniable connection to it (Gillies Jones, 2009).

Figure 13 Tony Hanning ‘AQA’ 2008.
height 37 cm Triple overlay cameo glass

Tony Hanning (1950) creates artwork that explores the role of memory and place in the inducement of reverie. He sandblasts through layers of coloured glass onto blown forms to create a sense of place. Hanning’s work involves considerable drawing and research into narratives that present a range of visual stimuli that could loosely be classed as "things we remember never having seen" (Hanning, 2010). The imagery in Hanning’s artwork is often very detailed as seen in ‘AQA’ (Figure 13).

Figure 14 Katrin Maurer ‘The Spectacle’
2007. Engraved object from a series of 16

Katrin Maurer (1975) produced the installation ‘The Spectacle’ (Figure 14) in 2007. The background to the artwork is the radioactive accident that occurred in the Chernobyl Nuclear Power Plant in 1986. The installation consists of a flexible stainless steel frame with 195 individual white glass elements with sandblasted text that can be physically turned. The sandblasted texts on each element relate to memories of the 1986 accident. The visual subtleness of the light texts on white represents the invisibility of radioactivity (Maurer, 2006).

Figure 15 Ingrid Nord 'Urban Life' 2005. 42 cm high Blown and sandblasted glass

Ingrid Nord (1980) created this series of blown glass vessels entitled 'Urban Life' (Figure 15) using the process of sandblasting. This allowed her to create images on both the surface of the forms and within the blown glass forms. She worked through the layers of the glass to create a three-dimensional effect. Her work is based on the contrast between light and dark, taking inspiration from graphic art. She recreates imagery from the urban landscape in a simplified manner and aims to capture the noise and movement in the landscape and create an atmosphere of organised chaos (Nord, 2005).

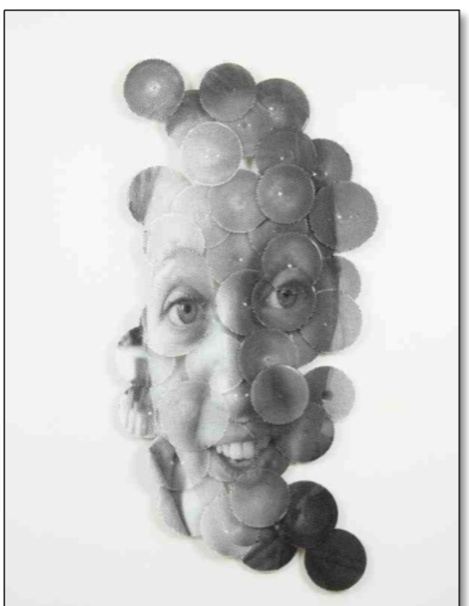


Figure 16 Jeffrey Sarmiento 'Resolution' 2005. 150 cm x 91cm x 15 cm Sandblasted and enameled blown glass

Jeffery Sarmiento (1974) used photosensitive sandblast resists in combination with blown glass to create the artwork entitled 'Resolution'. (Figure 16). Producing a photo resist stencil containing an image that was applied and sandblasted to blown plates created 'Resolution'. The areas removed by sandblasting were filled with cold enamel that was subsequently fired. (Sarmiento, 2010).

The use of sandblasting in combination with blown glass has resulted in a process known as ‘graal’. To create a graal embryo, layers of different coloured glass are built up and blown into a bubble or bowl form and then cooled down. Once cool, a resist is applied and the layers of the coloured glass not covered by the resist are abraded away using the process of sandblasting or engraving. The bubble or bowl is picked back up on a blowing iron and worked further at the furnace and glory hole, resulting in a more fluid decorative effect due to the movement and manipulation of the hot glass. The following information demonstrates the diverse range of visual effects that can be achieved by artists who use the graal process to create decoration.

Figure 17 Clare Henshaw ‘Vessel’ 2007. 40 cm x 26 cm Two-part overlay, blown glass vessel

Clare Henshaw (1964) creates free blown, vessel forms that are cased with colour both outside and inside. Using the 'graal' technique, she sandblasts through the layers of glass to reveal the inside colours. As the piece is blown into its final shape, the patterns generated become integral with the form. In the artwork entitled ‘Vessel ‘(Figure 17), Henshaw focuses on light and colour and this artwork is very different to the heavily engraved figurative narrative that defined her earlier pieces (Henshaw, 2008).

Figure 18 **John Brekke** **'**Minoan Octopus' 2010. 30 cm x 20 cm Blown and sandblasted glass

John Brekke (1955) describes himself as a mark-maker. His making of marks, lines, scratches, letters and strokes is central to his work and he produces artwork that embraces light, tone and texture. For the last ten years he has created both painted and glass artworks. In his glass artworks he uses the process of graal to create a range of vessels. He has also created a number of patterned and textured glass roundels by etching the surface of the glass to reveal layers of colour (Brekke, 2010). 'Minoan Octopus' (Figure 18) is an example of his artwork produced using the graal process.

Figure 19 **Per B Sundberg** **'**Litograal' 2003. Blown glass with sandblasted porcelain enamel

Per B Sundberg (1964) developed a process involving the creation of his own resist patterns for sandblasting. This process is similar to graal and involves imagery being sandblasted directly on to a thin layer of ceramic enamel to give the impression that the glass has been printed. He named this process 'litograal' (Glass Art Society Journal, 2007). 'Litograal' (Figure 19) shows the artwork he produced using this process. An interesting feature of Sundberg's work is that he gave his new processes a title to add to the specialised vocabulary of glassmakers. Sundberg developed this process whilst he was employed as a designer at Orrefors and his work is part of the history of the company.

2.3.2 Adding elements to create decoration

Printmaking processes, such as screenprinting involve the addition of ink to a surface to create decoration. When decorating blown glass forms there are also processes that involve adding other elements to the surface of a glass form to create decoration. The focus of this research, embedding printed transfers in layers of blown glass forms, is an example of an added element to create decoration. Another example is the process of enameling where vitreous pigments coloured with metallic oxides are fired onto the surface of the glass. The following information demonstrates the diverse range of visual effects that can be achieved by artists who add elements, such as enamel to blown glass forms to create decoration.

Figure 20 - Cappy Thompson. Safe Passage, 2000, 67cm x 37cm x 37cm. Vitreous enamels reverse painted on blown glass.

Cappy Thompson (1952) enamels pictorial narratives on to both panels and vessel forms. She believes the vessel exists on an intimate scale, relates to the individual in its form and function and is a nearly perfect structure for her narrative. The transparency of glass allows the painting to become sculptural, seen from one side through to the other, changing as the viewer circumambulates the structure. She works with coloured vitreous enamels to transfer her picture-poems onto glass vessels (Thompson, 2004). Thompson begins by commissioning blanks. Next she draws the entire design on the outside of the vessel with a black marker and positions the piece on a light table. Working horizontally, she retraces the drawing with black enamel on the interior, and then fires the vessel. Using the grisaille process, Thompson applies a wash of grey paint over the interior drawing. She scrapes away the grey to create highlights, resulting in a tonal quality. She then fires the vessel for a second time.

Finally she paints the various elements of the scene with bright enamels and fires the form once or twice until she achieves her desired colour palette. In each case the resulting image resembles a stained glass scene: bright jewel-toned colors surrounded by thick black lines (Pascucci, 2004). 'Safe Passage' (Figure 20) is an example of Thompson's detailed pictorial narrive and her use of a multi-coloured palette.

Figure 21 David Walters 'You Can't Go Home Again' 2007. 65 cm x 22 cm x 22 cm. Blown glass and enamel paint

David Walters (1968) creates functional glass but he is best known for his unique vessels enameled with detailed narrative drawings that reflect his printmaking background (Wheaton Arts, 2010). He adds his own personal interpretation in an allegorical and metaphorical style using familiar children's stories or fairytales. There are clear relationships between Walter's artwork and the work of printmakers. Walters is also influenced by early Christian or Byzantine painted mosaics and, as seen in 'You Can't Go Home Again' (Figure 21), his artworks are primarily black and white with an occasional accent colour and he often integrates text in his artwork. Whilst undertaking a fellowship at the Creative Glass Centre in Spring 2004, Walters created vessels decorated with enamels which he then removed by scrafitto or sandblasting once they had been fired. He felt that combining additive and subtractive methods allowed him greater freedom.

Figure 22 Walter Lieberman 'Alone Together' 2002. 50 cm x 40 cm x 12 cm Enamel fired on blown glass

Walter Lieberman (1954) enamels onto glass. He has mastered the art of layering his enamels. After firing, colour is removed to reveal what is beneath. The enamel can be applied in multiple thin transparent layers. The enamel is fired between layers. Sometimes it may be fired as many as ten or twenty times. This approach is similar to glazing in oil painting. 'Alone Together' (Figure 22) creates a sense of richness and depth (Lieberman, 2006).

Figure 23 -Joanna Manousis 'Self-Contained Spray' 2007. 38 cm x15 cm x 15 cm Blown and kiln-cast glass, hand-painted enamel

Joanna Manousis (1984) creates work that focuses on the combination of two-dimensional imagery within three-dimensional forms, giving kiln-cast, and blown glass sculptures both physical depth and narrative. 'Self-contained Spray' (Figure 23) was fabricated using the 'graal' process. A glass bubble was blown, sandblasted and hand-painted with high firing enamels. The graal portraying the chosen imagery was brought up to the peak temperature in a kiln, re-attached to a blow-pipe and encased in glass. After cooling it was blown out to the required bottle shape and the underside polished to peak clarity. The spray-can nozzle attachment was hand-carved in wax, and, using various mould making processes, cast in crystal in a kiln. Acid polishing produced the clear finish and the spray-can nozzle was then UV bonded to the bottle canister to create the finished sculpture (Manousis, 2007).

Photographic imagery can be added to glass forms to create decoration. This is achieved by applying photographic emulsion or liquid light to the surface of the glass form and exposing a positive image into the emulsion. The following information demonstrates the visual effects that can be achieved by artists who add photographic imagery to blown glass forms to produce decorative artwork.

Figure 24 Nicole Ayliffe 'Optical Landscape – Forest' 2007. 26 cm x 18 cm x 7 cm Hot blown glass and photographic image

Nicole Ayliffe (1977) is known for her use of photographic imagery in her artwork. Ayliffe applies the imagery once the work has been blown and cold-worked. She states that she intentionally places her imagery on the back of the form to give the impression that the image is trapped within the piece (Fusion Gallery, 2006). 'Optical Landscape' (Figure 24) demonstrates the potential for combining photographic imagery with blown glass.

Other elements of glass such as glass powder, glass frit, glass rods and glass shards can be added to blown glass forms to create decoration. The following information demonstrates the visual effects that can be achieved by artists who add other elements of glass to blown glass forms.

Figure 25 Mark Peiser 'Summer Cattails' 1978. Hot worked glass vessel

Mark Peiser from America became involved with the Studio Glass Movement in 1967. He is recognised for his unique and individualized approach. In his artwork 'Summer Cattails' (Figure 25), the form is blown and the imagery applied using the process of lampworking. Peiser has a background in engineering.

He reports that he was astounded by the lack of technical information available and pertinent the small studio. Peiser quickly resolved to pursue rather vigorously an understanding and control of blowing techniques, and the understanding and capabilities of making his own glasses and colors. He feels that this understanding and control are the tools of his trade (Peiser, 2005).

Figure 26 Joey Kirkpatrick and Flora Mace 'Cylinders' 1979. Blown glass form with added metal outlines and coloured glass

Joey Kirkpatrick (1952) and Flora Mace (1949) worked together to create the artwork 'Cylinders' (Figure 26). The artwork was inspired by a series of drawings and the challenge was to translate the linear quality of drawings into glass by applying them onto a blown glass form. To replicate the images in glass, bending thin metal wires into similar shapes and embedding them onto the surface of a glass vessel during the blowing process created the pencil lines. Eventually color was added by melting different colored glass threads within the wire structure prior to being picked up on the vessel. As Kirkpatrick and Mace developed this technique of applying decoration, their artistic vision came together and their collaboration began.

2.3.3 Decoration made from glass that is subsequently used to create the form

The following information demonstrates the diverse range of visual effects that can be achieved by artists who use decoration made from glass that is subsequently used to create the form. The novel print inspired processes detailed in Chapter 4 initially produced two-dimensional sheets that had the potential to be turned into three-dimensional forms. The roll-up process facilitated this crossover from two-dimensional to three-dimensional.

Figure 27 Scott Chaesling 'Re-Unification' 2005. 54 cm x 25 cm x 25c m. Fused and rolled transparent and opaque glass with painted narrative image

Scott Chaseling (1962) was one of the first artists to use the roll-up process in his artwork and he spent seven years developing and researching the process of painting, fusing and blowing hand-rolled sheet glass. With the roll-up process Chaseling wanted to create a new way of assembling the form to allow his imagery to stay prominent. The roll-up process enabled Chaseling to display his narrative stories, with brilliantly coloured paintings on the interior and exterior surfaces of his glass vessels. In 'Re-Unification' (Figure 27) his narrative imagery was portrayed using bright expressionistic colors and reflected the subtle views of Chaseling's intimate encounters. The inner glimpse of Chaseling's psyche is further enhanced by the interior images, which offer a completely different scene for the viewer. Chaseling originally trained as a sculptor and he has a long history in glass participation in an international arena. Chaseling's work is included in major collections such as the National Gallery of Australia, the Museum of American Glass in New Jersey USA and the 21st Century Museum of Contemporary Art in Kanazaw Japan (Jacobson, 2006).

Figure 28 Klaus Moje 'Niijima 10' 1999. 40 cm x 7 cm x 7 cm Glass roll-up

Klaus Moje (1936) is known for his process that has similarities to Italian glass Murrine or cane processes although they differ significantly in that he uses sheet glass as the foundation, resulting in a tighter structure with more varied design. Moje believes constructing blown forms without the use of a furnace, frees him from the burden of expensive facilities and has allowed him to develop a more considered and conceptual approach. Making his artwork is labour intensive though meditative (Di Marzo, 2009). Moje's work is an exploration of color, the kind of saturated, luminescent color that is only possible with glass. He chose early in his career to work with a standardised set of reductive shapes such as a circle and a square. In later years, he expanded his repertoire to include simple cylinders and boxes, and most recently, flat panels. Within this fairly rigid format, he has experimented with dramatic color contrasts and with geometric and abstract pattern to create Niijima (Figure 28).

2.4 Discussion of visual qualities offered by glass and print processes

Table 1 summarises the decorative potential of the processes of engraving, sandblasting enameling and using screenprinted/digitally printed transfers. The table highlights the strengths and weaknesses of each particular process in terms of its decorative potential.

Table 1 Summary of visual qualities that can be created using existing glass decoration processes

	Engraving	Sandblasting	Enameling	Screen printed transfers	Digitally printed transfers
Detailed imagery	Can be created	Can be created	Can be created	Can be created	Can be created
Photographic imagery	Difficult to re-create and relies on the skill of the engraver	Can be re-created but photographs need to be translated into halftone imagery meaning they appear pixilated	Difficult to re-create and relies on the skill of the enameller	Can be re-created but photographs need to be translated into halftone imagery meaning they appear pixilated	Can easily be created without having to alter the imagery
Tonal imagery	Simple tonal qualities can be created	Simple tonal qualities can be created	Complex tonal qualities can be created	Cannot be created with hand screenprinted transfers unless translated into halftone imagery meaning it appears pixilated	Can be created
Text	Can be created but relies on the skill of the engraver	Can be created but anything below point 10 text could be difficult to read	Can be created but relies on the skill of the enameller	Can be created	Can be created
Varied colour palate	Difficult to create and reliant on the skill of the glassblower to produce an embryo made up of multiple thin layers of colour	Difficult to create and reliant on the skill of the glassblower to produce an embryo made up of multiple thin layers of colour	Can be created but involves multiple kiln firings	Can be created but involves drying time after each colour is printed and registration of imagery before each colour is printed	Can be created easily
Texture	Varying depth of texture can be created	Varying depth of texture can be created	Difficult to create as multiple layers of enamel would be needed to build up texture and the texture would be at risk of melting during firings	Difficult to create as multiple layers of enamel would be needed to build up texture	Not possible to create
Potential for embedding	Can be embedded	Can be embedded	Can be embedded but high firing enamels are needed to prevent burning out	Can be embedded but high firing enamels are needed to prevent burning out	Can be embedded but high firing enamels are needed to prevent burning out

The first comparison was to look at the detail of the imagery each process was capable of creating. In the artworks using the processes of engraving, enameling and sandblasting, the imagery was often complex and incorporated a variety of components such as fine lines, figures, text and pattern. This variety of components is seen in Coleman's artwork (See Figure 7). This was also evident in enameling where enamels were often used to paint detailed pictorial scenes. Thompson's artwork demonstrates this (See Figure 20). Using printed transfers offers the potential to create equally detailed imagery. In enameling and engraving, the creation of imagery is entirely dependent on the drawing skills and mark making abilities of the artist whereas with printed transfers, imagery is easier to create and there is scope for combining hand drawn artwork with digital artwork. In addition using printed transfers allows the imagery to be perfected two-dimensionally before it is applied to the three-dimensional form. Interestingly a number of the featured artists have a background in printmaking prior to working with blown glass. This includes Brekke (Figure 18), Gillies Jones (Figure 12), Walters (Figure 21) and Peiser (Figure 25). These artist's have used their background knowledge in printmaking when considering the way they decorate their blown glass forms.

The visual appearance of using photographic imagery in each process was compared and contrasted as this is one of the strengths of using printed transfers. From the five glassmaking processes reviewed, using digitally printed transfers was the only process that facilitated the exact replication of a tonal photographic image. Screenprinted transfers and sandblast resists could also be used to reproduce photographic imagery if the photograph had been translated into a halftone image. Halftone imagery has a particular visual appearance as it is made up of dots. An example of this appearance can be seen in Sarmiento's artwork (Figure 16). The reproduction of photographic imagery in artwork that is enameled or engraved would be more complex and would be reliant upon the skill of the artist. All of the processes reviewed have the potential to transfer text onto blown glass. When using UV curable sandblast resists and screenprinted transfers, the text could either be hand written or computer generated, resulting in a greater variety of decoration. Maurer's artwork (Figure 14) illustrates computer generated sandblasted text as oppose to Fonde's hand engraved artwork (Figure 11).

Colour can create an interesting decorative effect. It was noticeable that the enamellers used a greater variety of colours in their work compared to the engravers and sandblasters. This extensive colour palette can be viewed in Thompson's artwork (Figure 20). It should be noted that using a large colour palate could extend the making time for the artist who uses the process of enameling as each colour may need to be fired separately. This could add a risk factor to the process as the glass would be more likely to break during firing due to stress in the material. The greater number of stages involved, the greater the risk of the glass breaking. One artist who has mastered the art of layering his enamels is Lieberman (Figure 22) who reports that he often applies and fires up to twenty layers of enamel. This element of risk is minimised when using coloured screenprinted transfers. With screenprinted transfers, although each colour is printed separately onto the paper, the drying time of each colour is considerably shorter than the firing cycle required to harden the enamels. As the enamel dries on the surface of the paper before it is applied, there is no risk to the glass form. Alternatively a coloured digital transfer can be quickly printed from a specially designed printer to minimise the time spent producing the transfers.

One advantage of using the processes of engraving and sandblasting, is that texture can be created, potentially adding to the decorative quality of the artwork. Stern in particular highlights how texture is an important part of his artwork (see Figure 10). Pennell (Figure 9) uses the texture in his engravings to emphasise the tonal qualities of his imagery. Texture is more difficult to achieve with the process of printed transfers and enameling. Multiple layers would have to be built up, with each layer requiring drying and possibly firing time.

This research particularly focuses on the process of embedding printed imagery into blown glass forms and each of the five processes described in Table 1 was deemed suitable for embedding. If using enamels, screenprinted transfers and digitally printed transfers, special high-firing enamels would be necessary to prevent the image from burning out. However, it is possible to create the illusion that imagery is embedded by applying imagery to the back or the inside of the form once it has been blown.

Ayliffe's artwork (See Figure 24) demonstrates this. Thompson (See Figure 20) also achieves the illusion that her imagery seems trapped in the glass, by reverse painting her detailed pictures onto the inside of her vessels.

2.5 Practical issues that relate to using existing glass decoration processes

When an artist is considering the most appropriate process to use to display their imagery in or on blown glass forms, it is important to take into account the practical issues that relate to each process. Practical issues include how easy it would be to re-create the same imagery in different artworks, what equipment is needed, are any specialist skills needed and consideration of the production costs involved in making the original artwork and subsequently recreating the artwork at a later date. Practical issues may affect the artist's choice of process depending on the purpose of the artwork e.g. one off piece for an exhibition, multiple pieces for sale, the budget for the artwork, the facilities available to make the work etc.

Table 2 summarises the practical issues relating to the five glassmaking processes and highlights the strengths and weaknesses of each process.

Table 2 Summary of practical issues that relate to using existing glass decoration processes

	Engraving	Sandblasting	Enameling	Screen printed transfers	Digitally printed transfers
Ease of reproduction	Difficult to reproduce exact decoration and relies upon the mark making skills of the engraver	It is possible reproduce sandblasted decoration if UV curable resists or vinyl cut stencils are being used as these processes do not involve hand cutting	Difficult to reproduce exact decoration	It is possible to reproduce screenprinted decoration but this could become more difficult when multiple coloured images are being used	It is possible to reproduce exact decoration using this process
Equipment needed	Lathe	If using UV resist a UV light box and washing out area would be needed as well as the sheets of resist If using vinyl cut stencils a vinyl cutter would be needed as well as the vinyl to cut	Variety of brushes Low fire enamels	Screens, UV Light box,Washing out area with power washer to clean out screens Transfer paper Printing medium High fire enamels Printing bed Squeegee Screen strip	Digital transfer printer
Skills/ knowledge required	Engraving skills	Knowledge of screenprinting processes would be useful when working with UV curable resists Specific knowledge relating to the computer software needed to program the vinyl cutter would be useful	Drawing and painting skills	Knowledge of screenprinting processes	Knowledge relating to the digital formatting of imagery would be useful
Production costs	The required equipment can be costly to purchase but once bought can be cheap to use	UV curable resists are expensive to purchase but relatively quick to use	Relatively inexpensive	A UV light box is expensive to purchase but smaller and cheaper alternatives can be used Initially screens would have to be purchased Water-slide transfer paper would have to be purchased	A specialist printer to print the transfers would have to be purchased Alternatively there are a number of companies who offer a service for printing transfers

One advantage of using screenprinted transfers/digitally printed transfers is the ease of reproduction of imagery for multiple bodies of artwork or when an artwork needs to be recreated at a later date. This is also possible with the process of sandblasting if resists are used. With processes such as engraving or enameling, the artist would have to create every piece individually. Millard (Figure 9) states that it can take up to fifty hours to hand engrave one piece of artwork. Producing multiple reproductions using this process would be a time consuming exercise and would inevitably add to the cost of the artwork. With each process discussed above, specialist equipment is needed and the artist would need knowledge of both using the medium of glass and working with specialist equipment. With engraving and enameling, the artist would need to be a proficient drawer/painter. The production costs of each process varies and includes buying, running and maintaining specialist equipment as well as purchasing the materials needed to make the artwork. For example using screenprinted transfers involves purchasing special transfer paper. Sandblasting involves purchasing UV curable resists. These extra costs need to be built in to the cost of the finished artwork.

2.6 How the limitations might affect artworks created by embedding the imagery produced using existing glass decoration processes

Table 3 Description of the limitations that could occur when embedding screenprinted transfers into layers of blown glass and inflating the form

	Engraving	**Sandblasting**	**Enameling**	**Screen printed transfers**	**Digitally printed transfers**
Stretch and distortion of imagery	The imagery would stretch and distort depending upon the complexity of the form produced and the skill of the glassblower	The imagery would stretch and distort depending upon the complexity of the form produced and the skill of the glassblower	The imagery would stretch and distort depending upon the complexity of the form produced and the skill of the glassblower	The imagery would stretch and distort depending upon the complexity of the form produced and the skill of the glassblower	The imagery would stretch and distort depending upon the complexity of the form produced and the skill of the glassblower
Stretch and distortion of imagery	The imagery would stretch and distort depending upon the complexity of the form produced	The imagery would stretch and distort depending upon the complexity of the form produced	The imagery would stretch and distort depending upon the complexity of the form produced	The imagery would stretch and distort depending upon the complexity of the form	The imagery would stretch and distort depending upon the complexity of the form

Density of imagery	There is potential to create dense imagery as the layer of glass (usually coloured) that is cut away to create the imagery when engraving could be applied quite thickly (at least 1mm) However it would be difficult to accurately control how much glass is removed during engraving (this relies on how much pressure the maker asserts). This may result in inconsistent density	There is potential to create dense imagery as the layer of glass (usually coloured) that is removed to create the imagery when sandblasting could be applied quite thickly (at least 1mm) However it would be difficult to accurately control how much of the layer is removed during sandblasting (as it relies upon the eye of the maker). This may result inconsistent density	Dense imagery could be created by applying multiple layers of enamel to the surface of the glass but drying time and possibly firing time between each layer would be needed	Dense imagery could be created by screen printing multiple layers of enamel on top of each other but this would involve drying time between each layer and accurate registration of the screen and transfer paper to ensure that the image was not compromised	Dense imagery would be difficult to control with this process as the amount of enamel deposited onto the surface of the transfer paper is pre-determined by the specialist digital printer used
Detail of blown image	The detail of the image would deteriorate in sharpness and clarity according to how much the imagery was enlarged as the glass form was blown	The detail of the image would deteriorate in sharpness and clarity according to how much the imagery was enlarged as the glass form was blown	The detail of the image would deteriorate in sharpness and clarity according to how much the imagery was enlarged as the glass form was blown	The detail of the image would deteriorate in sharpness and clarity according to how much the imagery was enlarged as the glass form was blown	The detail of the image would deteriorate in sharpness and clarity according to how much the imagery was enlarged as the glass form was blown
Compatibility of process	To ensure compatibility the glass form containing the engraved imagery and the layer of glass embedding the engraved imagery would need to be of a compatible co-efficient	To ensure compatibility the glass form containing the sandblasted imagery and the layer of glass embedding the sandblasted imagery would need to be of a compatible co-efficient	To ensure compatibility the enameled imagery and the layer of glass embedding the enameled imagery would need to be of a compatible co-efficient	To ensure compatibility the screenprinted transfers and the layer of glass embedding the screenprinted imagery would need to be of a compatible co-efficient	To ensure compatibility the digitally printed transfers and the layer of glass embedding the digitally printed imagery would need to be of a compatible co-efficient

Health and safety issues relating to process	A dust mask is required to prevent inhalation of fine particles of glass which are created from cutting into the surface of the glass	A dust mask is required to prevent inhalation of fine particles of glass and sand which are created from blasting the surface of the glass Protective rubber gloves are needed to prevent sandblasting hands	Depending on the type of medium used to mix the enamel, issues relating to COSH would have to be taken into account A dust mask may be required when mixing to prevent inhalation of small particles	If the printing medium used to print the transfer is solvent-based strict health and safety guidelines would need to be followed Inhalation, ventilation and waste disposal of solvents need to be taken into account with this process A dust mask may be required when mixing to prevent inhalation of small particles	There are very few health and safety issues with this process

The first limitation considered was stretch and distortion after the imagery was embedded into blown glass forms and inflated. It was concluded that with every process inflation would result in stretch and distortion of the imagery. The amount of stretch and distortion would be dependent on the choice of form and the degree of inflation. During previous professional practice I often found that the choice of form emphasised or disguised the documented limitations of stretch and distortion.

A simple form was often the most successful choice. In a number of the featured artworks the artist had used a simple blown glass form to display their imagery. However, the form was undoubtedly chosen to display their imagery to the best advantage. For example, Stern's simple flat form enabled the viewer to focus on the surface colour and design (Figure 7). Hanning (Figure 13) justifies using a simple cylindrical form in his artwork. He states that using a regular wrap-around form for picture making creates the perfect canvas. It not only allows maximum coverage for the imagery and text, but it represents the surrounding world (Osborne 2005). Nord (Figure 15) used a simple form to display her sandblasted imagery. In this artwork the viewer immediately focuses on the artwork.

Chambers (1994) documents how Brekke uses a simple blown glass form because of its lack of pretension (Figure 18). It was noticeable that in several of the artworks the imagery had been added to the surface of the glass form once it had been blown and cold-worked. Henshaw's artwork (Figure 17) is an example of pattern that is integral with the form. This would ensure that stretch and distortion was minimal. An interesting feature in Manousis' artwork (Figure 23) is that she has used the limitation of stretch and distortion to enhance her chosen imagery that is in keeping with the concept behind her artwork. Moje (Figure 28) has chosen a simple form for a different reason. The rationale for this choice is that the roll-up process is more suited to a cylindrical form.

The second limitation considered was density of imagery following inflation. With engraved and sandblasted imagery, there is potential to create denser imagery as depth of glass removal can be controlled. With enameling, the density can be controlled by adding subsequent layers of enamel. With screenprinting it is also possible to overprint multiple layers of enamel to create a denser transfer. However, registration needs to be taken into consideration or the imagery will become blurred. Due to the fact that digitally printed transfers involve the use of a printer that controls the amount of enamel deposited onto the surface of the transfer, altering the density of the transfer is more difficult. In addition overprinting would be difficult due to problems with achieving the correct registration.

The third limitation assessed was detail of blown imagery when the imagery was embedded into blown glass forms. It was concluded that with every process inflation would result in loss of clarity of the imagery. The amount of clarity reduced would be dependent on the choice of form and the degree of inflation.

The fourth limitation assessed was compatibility of the process. In engraving and sandblasting this limitation is less of a problem as the decoration is being removed from the surface of the glass. With enameling and both screenprinted and digitally printed transfers where the imagery is being added to the surface of the glass, the enamel used would need to have the same co-efficient as the glass being used. High-firing enamels are required when embedding the imagery into layers of blown glass.

Typically high-firing enamels have been developed for the decoration of ceramics and because of this compatibility problems with the glass and the imagery may occur.

The final limitation assessed was health and safety in relation to the decoration processes. The health and safety risks associated with the processes of engraving and sandblasting are low. The main consideration to take into account is the risk of inhalation of fine particles of glass and sand. To prevent this the artist would need to ensure that they have the correct personal protection equipment such as a dust mask, safety goggles and protective gloves. Similarly the risks with enameling are fairly low. In contrast more care needs to be taken when using screenprinted transfers. This is because screenprinting involves the use of solvent-based printing medium. Although a water-based system has been developed (Petrie 2006) for use with screen-printed transfers, in my own work I have found that the solvent-based printing medium creates a denser transfer for embedding into blown glass forms. If using a solvent-based printing medium, COSHH guidelines would need to be followed. The use of solvents is not an issue when using digitally printed transfers as the transfers are generated using specialist printing equipment.

2.7 Summary of Chapter 2

The aim of chapter 2 was to position the research study in the wider field of glass and print. This was initially undertaken by reviewing existing literature. However, as literature was limited in terms of both technical information and artists who used a similar process to my own, it was necessary to extend the boundaries of the search. Applying printed transfers to blown glass forms is one of several glassmaking processes with roots in printmaking processes and considering these alternative processes, the artists who use them and the range of decorative effects that can be achieved, helped to define my own research. As I was approaching the study as a hot glassmaker rather than a printmaker, it also extended my own knowledge of various printmaking processes as well as other glassmaking processes. For example James' article gave insight into the production of the digital transfer system.

The methodology chosen to undertake this section of the literature review was reflective analysis of artworks with case studies of each artist. Comparing and contrasting the decorative potential of each process, the ease of use, the monetary and environmental costs etc enabled me to assess how embedding screenprinted transfers into layers of blown glass was a viable process for artists.

As no substantial body of information was available on the limitations I had encountered during previous practice, this was also an opportunity to explore in depth whether there was documented information on limitations encountered from artists using alternative glassmaking processes with printmaking roots. Again relevant technical information was scarce and if limitations had been experienced, they were rarely mentioned. On occasions an artist might have stated that they had found making a particular piece of artwork challenging but they did not elaborate further.

The literature review confirmed that there is an emerging interest in the subject of glass and print. The staging of the Glass and Print Symposium (2006) at the University of Sunderland indicated that there is an interest in the combination of glass and print for students and professional practitioners.

The Glass and Print Symposium was an opportunity for artists interested in glass and print to meet, to enrich their practice and place glass and print in a broader context. Petrie's handbook is further indication of interest. However, despite this positive trend, there is still limited technical information on the processes that artists use to produce their artworks and the problems they encounter. The following chapters will consider novel ways of combining glassmaking and printmaking to decorate blown glass forms. From the perspective of an artist combining glass and print, it will also build upon the technical information currently available.

3. Demonstration of limitations

Chapter 3 relates to aim and objective 1 of the research. Retrospective analysis of previous artworks identified a number of limitations when embedding screenprinted transfers into blown glass forms. The role of tacit understanding contributed to my rationale to undertake a series of demonstrations to visually document these limitations. The demonstrations were undertaken using a screenprinted transfer with a standardised image designed to clearly show how the limitations found in previous practice affected the artwork during the glassblowing process.

3.1 Rationale for undertaking retrospective analysis of my previous artworks

At the outset of this research it was recognised that in the five previous bodies of artwork (See 3.2) strategies had been intentionally/unintentionally implemented to disguise any limitations that might occur during the blowing process. These strategies included choosing imagery that would not look obviously disproportionate after inflation e.g patterned rather than figural imagery. Choosing a simple form to accommodate the imagery such as a regular cylindrical form minimised distortion of the imagery during the blowing process. Only partially inflating the form resulted in the printed transfers being embedded into a thicker layer of glass and ensured minimal distortion of the imagery. It was recognised that decisions made during the making process were due to a degree of tacit understanding of materials and processes combined with designer instincts where knowledge guided actions.

3.2 Analysis of my previous artworks to highlight documented limitations

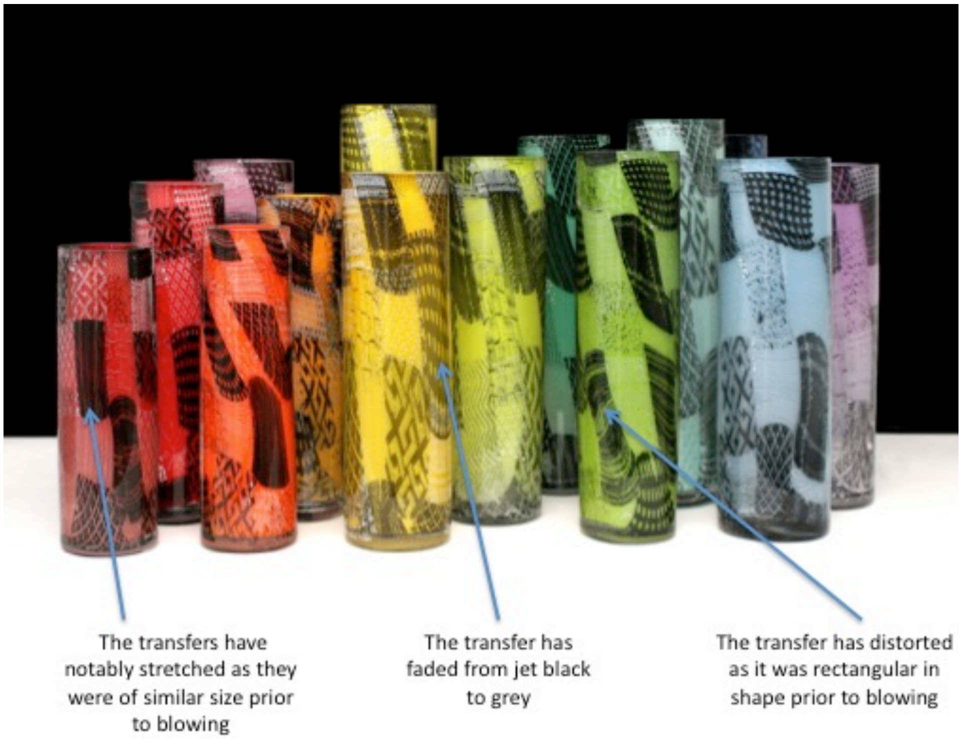


Figure 29 Kathryn Wightman 2004. 'Colour me a Rainbow' Blown glass forms with embedded screenprinted transfers - approximately 40 cm x 12 cm, 12 cm

In 'Colour me a Rainbow' (Figure 29), hand screenprinted black and white patterned transfers were embedded into layers of glass and blown to form a series of decorative cylindrical vessels. The two main limitations visible in this body of artwork are stretch/distortion and loss of density of the imagery that had faded from black to grey. At this early stage in using the process of embedding screenprinted transfers into blown glass forms, no strategies were employed to disguise the limitations. This was because this body of artwork was one of my first experiences of embedding screenprinted transfers into blown glass forms and I had no pre-conceptions of how the printed imagery would appear following inflation. Although these artworks were deemed marketable, obvious stretch and distortion of the imagery can be seen. However, I feel it does not detract from the overall decorative appearance of the artwork. This is because the chosen imagery consisted of an informal pattern and, although stretch and distortion altered the pattern, it did not make it unacceptable.

It was the fading of the imagery from black to grey in this artwork that I found particularly disappointing. The fading occurred during inflation as the cylinder was being stretched out to its final height. When stretching a cylinder during the blowing process, the bottom section of the form experiences greater elongation and results in asymmetry with the transfers at the bottom of the form stretching and fading more than the transfers at the top. Asymmetry can affect the visual appearance of the artwork as the eye tends to be drawn to the denser/blacker areas of the form.

The sandblasted silhouette draws immediate attention from away the printed transfer, but on close inspection the transfer looks slightly faded and distorted

Figure 30 Kathryn Wightman 2004. 'Who do you want to be today?' (Sexy Bitch*)* Blown glass forms incorporating screenprinted transfers and sandblasted silhouette - 50 cm x 20 cm x 10 cm

‘Who do you want to be today?’ (Figure 30), is a series of five blown glass vessels in which patterned screenprinted transfers were applied to five different coloured embryos and embedded into a layer of glass. Each embryo was overlaid with a layer of white powdered glass to create a two-coloured embryo. The embryos were sandblasted with ten different silhouettes, one on the front and back of each embryo. Finally the embryo was picked up, encased in a gather of glass and blown and shaped using a cork pad to form a flat teardrop vessel. Each individually shaped silhouette and corresponding pattern represented a different feeling or an individual personality trait e.g. Plain Jane, Sexy Bitch.

The main limitation visible in this artwork is stretching of the imagery. Anticipating that stretching of the imagery would occur, particular attention was paid when choosing an appropriate silhouette. The female silhouette was chosen as I felt elongating the female form would enhance it rather than detract from it.   Manipulating the female form in this way is a tactic widely used in magazines today.

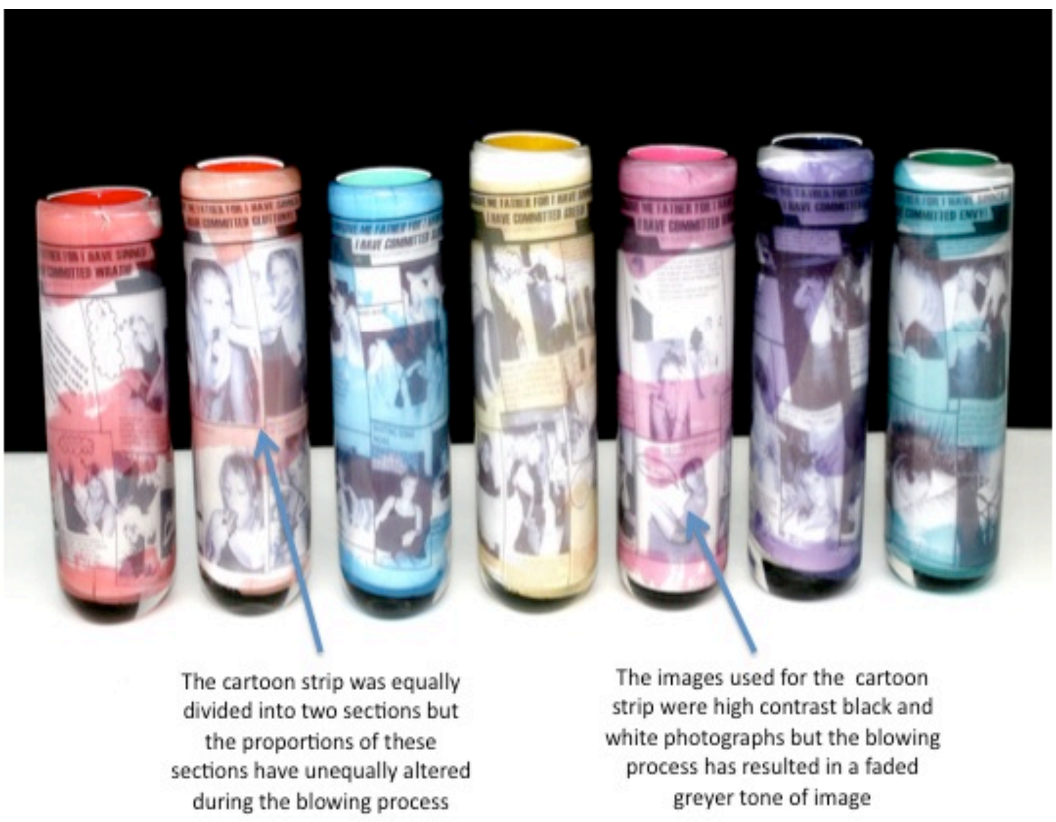


Figure 31 Kathryn Wightman 2005. ‘Forgive me Father for I have Sinned’ Seven free blown glass cylinders with embedded digitally printed transfers – 45 cm x 13 cm x 13 cm

‘Forgive me father for I have sinned’ (Figure 31), is a series of seven cylindrical glass vessels embedding commercially produced digitally printed, cartoon strip style transfers, displaying personal iconography and playful narrative. The tongue in cheek narrative recounted a personal seven deadly sins adventure resulting in a modern day twist on an ancient theme and documenting a moment in history. The aspiration behind this artwork was to tell a story and to preserve a moment in time. Sunderland Museum purchased this artwork in 2010 as part of their permanent decorative glass collection.

In creating this artwork it was considered essential that stretching of the imagery was kept to a minimum. This was because it contained both photographic imagery and narrative text and being able to read the text that was linked to the photographic imagery was imperative in understanding the concept behind the artwork. Figure 32 shows the photographic and textual content of the artwork prior to embedding.

Figure 32 **Kathryn Wightman** 2005. ‘Forgive me Father for I have Sinned’ Imagery prior to embedding into blown glass form.

The strategy employed to reduce stretch, was to develop an embryo that resembled the shape and proportions of the finished object. Although this was an effective strategy, it did not alleviate the limitation of stretching completely.

It was anticipated that the imagery would fade during the blowing process as this was a consistent finding in previous work. This did occur and it was noticeable that the fading was greater with the digitally printed transfers than with the hand screenprinted transfers. However, as the fading occurred very evenly all over the form, attention was not drawn to one particular area and it was, therefore, deemed acceptable.

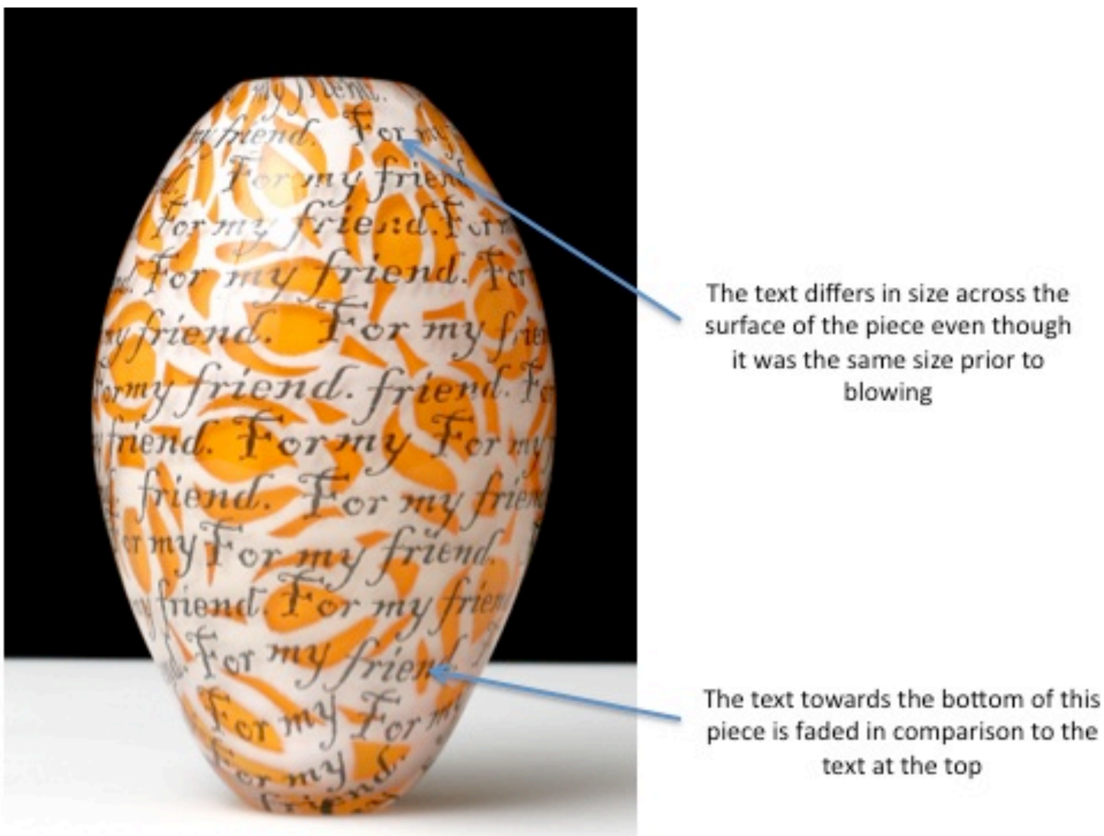


Figure 33 Kathryn Wightman 2006. 'Say it with flowers' (Tulip). Blown glass form incorporating sandblasted flower pattern and screenprinted transfers of text - approximately 30 cm x 12 cm x 12c m

The series *'Say it with flowers...'* (Figure 33), consisted of seven blown glass forms incorporating sandblasted flower patterns and screenprinted transfers containing relevant text. Each flower pattern was accompanied by a different phrase for a special occasion e.g. clover image/good luck text. Originally the series was designed for a competition for Daum crystal and if chosen as being suitable, the artwork would have been manufactured using the lost wax casting technique. The pieces were not chosen so the idea was adapted for blown glass at a later date.

The main limitation that can be seen in this artwork is stretch and this can be seen through the variation in the size of the text. Prior to inflation the text was the same size all over the form whereas post blowing it differed in size in particular areas. In addition there was obvious fading of the text, particularly at the bottom of the form. In this series of seven vessels, each vessel was a different shape and consequently it was noticeable that certain forms were more successful than others.

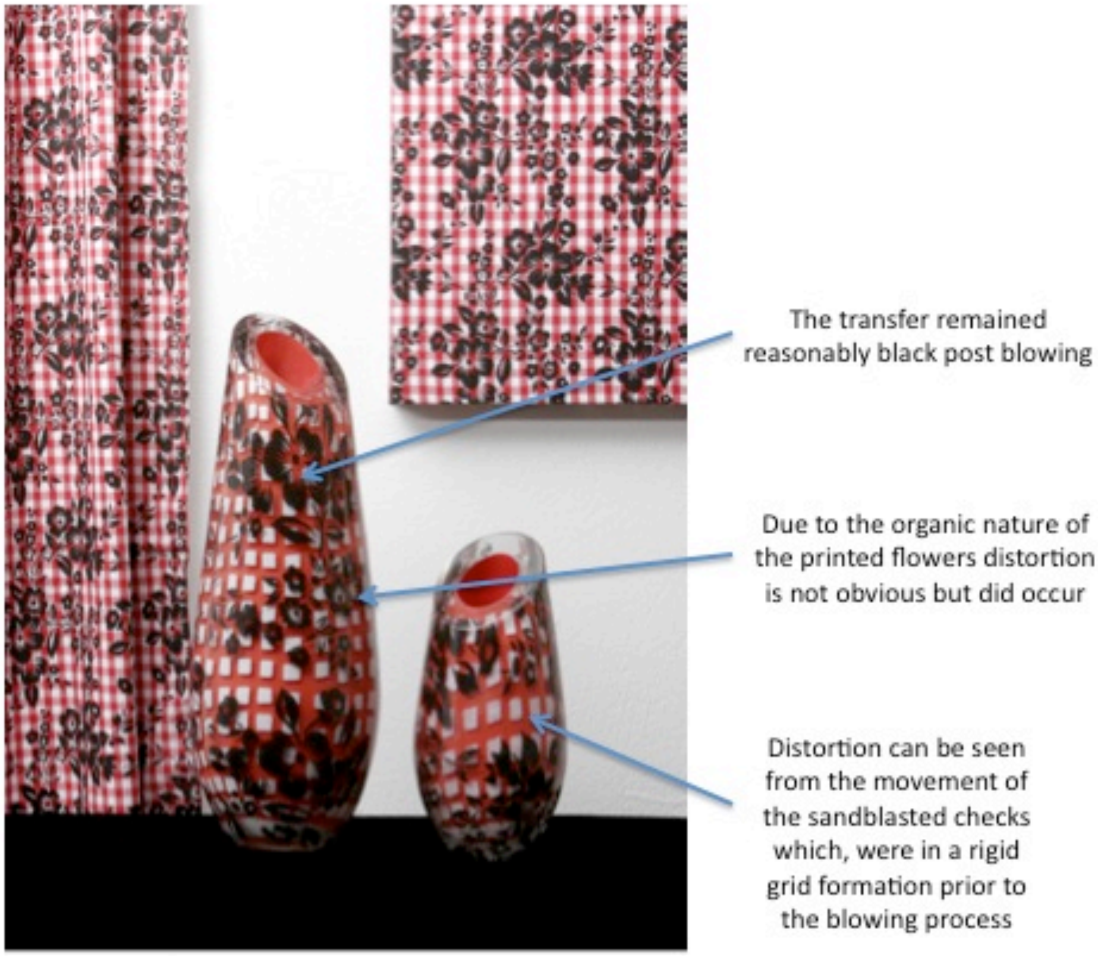


Figure 34 Kathryn Wightman 2005. 'Dress up your home'. Blown glass forms incorporating sandblasted checked pattern and screenprinted floral transfers

'Dress up your home' (Figure 34), incorporated a sandblasted pattern onto which hand screenprinted floral transfers were applied, embedded into layers of glass and subsequently blown to form vessels. The main limitation visible in this series of work is distortion of the sandblasted checked pattern. It is noticeable that the sandblasted checks appeared more distorted than the hand screenprinted flowered transfers. This is because the brain immediately recognises that the more rigid checked pattern is distorted and does not look like we expect it to whereas the organic nature of the printed flowers ensures that the distortion is less obvious. Tacit understanding ensured that the density of the imagery in this work was maintained. This was achieved by using a higher ratio of enamel to solvent-based screenprinting medium.

To complement this series of artwork, the process of printmaking onto fabric was explored in order to produce coordinating soft furnishings. Using an automated rotary screen pigment print system at Sharps Fabric Printers Limited, the floral design was printed onto checked gingham fabric. This exercise gave insights into how printmaking is used in the textile industry.

The above artworks are examples of the range of visual effects that can be achieved by combining and layering printed transfers with other blown glassmaking processes such as graal as well as cutting and polishing techniques. Taking into account the fact that tacit knowledge played a role in disguising the limitations in these artworks, it was deemed necessary to clarify the limitations in a formal way using a standardised image specifically designed to highlight the limitations during the blowing process.

3.3 The role of the standardised screenprinted transfer to visually document the limitations

The standardised screenprinted transfer was designed to demonstrate how imagery can be altered when printed transfers are embedded into blown glass forms. The image chosen for the transfer included a number of different components to demonstrate how each limitation affected different styles of imagery in different ways. A black image rather than a coloured image was used because, black is a strong colour that can be clearly seen and therefore fading would be clearly visible. Colour would have complicated the demonstrations as it was an additional variable to control.

The components in the standardised image included (Figure 35):

- **Horizontal lines/vertical lines** – horizontal and vertical lines are a good indictor of distortion. It is immediately obvious when a line is no longer straight.
- **Pattern** – pattern was used to assess how it differed from the original pattern after inflation or whether the pattern was enhanced or vitiated during the blowing process. It was also used to assess whether detail in the imagery was lost during the blowing process.

- **Dense areas of solid colour** – imperfections are more noticeable in solid areas of colour. Fading of the image is also more noticeable in dense areas, indicating a reduction in density.
- **Various sized text** (three font sizes) - this was to assess the printing performance of various point sizes and determine the optimum sized text
- **A universally recognised figure**– a universally recognised human image is a good indicator of acceptable distortion due to the proportions of the figure.

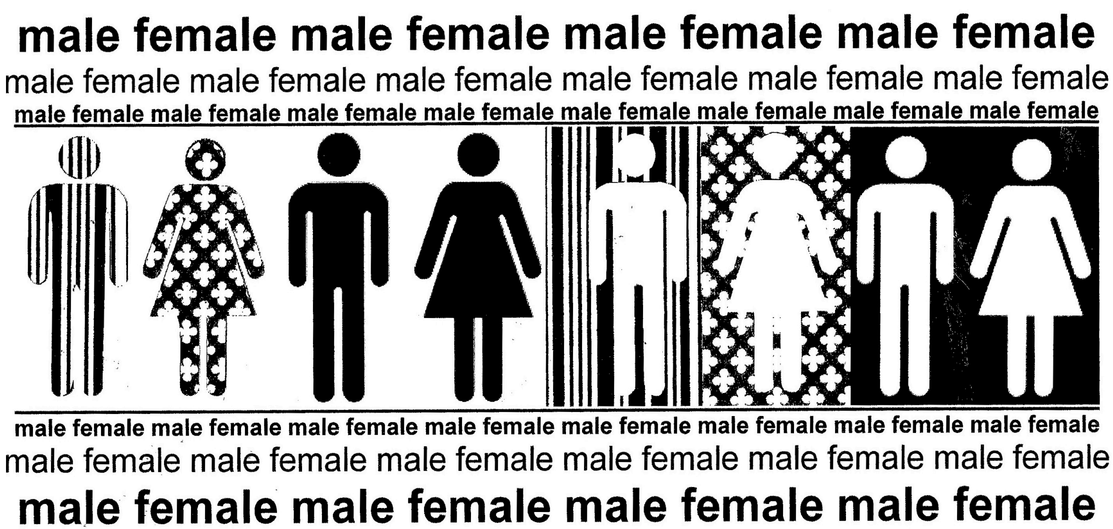


Figure 35 Standardised image prior to screenprinting

3.4 Creating and applying the screenprinted transfer

Once the content of the standardised transfer had been decided, the image was printed out onto a sheet of 'Folex' forming a positive that was used to transfer the imagery to the screen. A 24 x 19 inch Swedish redwood screen covered with a polyester monofilament fabric, was used to screenprint the transfer. To allow controlled quality of the ink, the screen was stretched tightly and evenly. The mesh size of the screen was 90t - determined by the complexity of the design. The number signifies the mesh threads per cm and the letter relates to the diameter of the mesh threads. The screen was coated in photo-emulsion.

Once dry the positive of the image was exposed on the centre of the screen to allow room for the ink and squeegee during printing. In line with previous practice, the image was exposed for approximately 21 light units on an exposure unit. The image was subsequently washed out to reveal the stencil. The screen was re-exposed on the light box to harden the emulsion prior to printing. The transfer paper used was U-Wet transfer paper. The printing medium used was solvent-based transfer printing medium (black ceramic on-glaze/under-glaze). In accordance with previous practice, the mixing ratio of medium to enamel was mixed to a ‘treacle like’ consistency. Post printing each transfer was checked to ensure the quality was the same and all components were intact. Inferior transfers were discarded. The transfer with the screenprinted image was applied to two pre-blown embryo forms. The first transfer was simply embedded into a layer of glass. The second transfer was embedded and blown approximately one hundred per cent larger. The findings are described in 3.5.

3.5 Observations of imagery following application to pre-blown glass forms

Figure 36 Demonstration of limitations - comparison between a transfer embedded in a layer of blown glass and a transfer embedded in a layer of blown glass and blown approximately 100% larger.

In the first demonstration the transfer was simply embedded in a layer of glass (Figure 36). It should be noted that the transfer printed with no imperfections and all assessable components were acceptable. On application the text at the top of the transfer did overlap slightly, causing creasing. Creases were also noted in some of the dense areas of colour. Each component of the image was in turn assessed for stretch, distortion density and detail and a decision made on whether the image was 'acceptable' or 'unacceptable' for use in professional practice. The parameters of 'acceptable' and 'unacceptable' were gauged from my own personal perspective as a professional artist.

Acceptable refers to artwork that I would be prepared to exhibit in an exhibition and unacceptable is work that is not of a high enough quality for sale or for exhibition purposes.

Table 4 Summary of observations after embedding the transfer in layer of glass

	Stretch	**Distortion**	**Density**
Horizontal/Vertical lines	Still straight – acceptable	Slight wavering but acceptable	Has maintained density – acceptable
Pattern	No change – acceptable	No obvious distortion – acceptable	Has maintained density – acceptable
Dense areas of colour	No change - acceptable	Minimal distortion – acceptable	Has maintained density – acceptable
Various sized text	Slightly more stretch at base in comparison to top but acceptable	Text has distorted slightly but still acceptable	Has maintained density – acceptable
Universally recognized figure	Proportions maintained – acceptable	Minimal distortion – acceptable	Has maintained density – acceptable

This table shows how simply embedding the transfer in a layer of glass produced a blown glass form in which all the components were deemed acceptable. The demonstrations were also undertaken to assess the compatibility of the printed transfer with the glass as well as assessing any health and safety issues. The glass and the transfer were compatible. Because of the solvent-based enamels used to print the transfer, there were health and safety implications.

Compatibility of decal	No cracking occurred. Even surface on inside and outside.
Health and safety	There are health and safety implications due to the solvent based printmaking process

In the second demonstration the transfer was embedded into a layer of glass and during inflation the transfer was enlarged one hundred per cent both horizontally and vertically (Figure 36). It should be noted that the transfer printed with no imperfections and all assessable components were acceptable. On application the text at the top of the transfer did overlap slightly, causing creasing. Creases were also noted in some of the dense areas of colour.

Each component of the image was in turn assessed for stretch, distortion density and detail and a decision made on whether the image was 'acceptable' or 'unacceptable' for use in professional practice.

Table 5 – Summary of observations after embedding the transfer in a layer of glass and inflating it by one hundred percent

	Stretch	**Distortion**	**Density**
Horizontal/Vertical lines	Stretched and became narrower but remained acceptable	Became wavy and not acceptable	Has dramatically faded - unacceptable
Pattern	Although there was obvious stretching of the pattern it remained acceptable	Has distorted but it added intrigue to piece and therefore acceptable	Has dramatically faded - unacceptable
Dense areas of colour	Remained in a block and therefore acceptable	Distortion evident but still acceptable	Has dramatically faded - unacceptable
Various sized text	There was more stretch at the base than at the top – however the text was still readable and therefore acceptable	Distortion evident but text still readable and therefore acceptable	Text at top denser than at base – overall unacceptable
Universally recognised figure	The proportions in the figure became unacceptable	Major distortion evident – not acceptable	Has dramatically faded - unacceptable

In this demonstration the majority of the components were found to be unacceptable and would have affected the decorative potential of the work. The demonstrations were also undertaken to assess the compatibility of the printed transfer with the glass as well as assessing any health and safety issues. Although no cracking occurred, there were signs of stress within the glass. Again the solvents used during the printmaking process raise health and safety issues.

Compatibility of transfer	No cracking occurred but there was an uneven surface on the inside of the vessel, suggesting the possibility of stress within the glass
Health and safety	There are health and safety implications due to the solvent based printmaking process

3.6 Summary of chapter 3

The purpose of the demonstrations detailed in this chapter were to address aim 1 of the research study – To clarify and visually document the limitations when embedding screenprinted transfers into blown glass forms. This was undertaken through objective 1 of the research study – To create blown glass with embedded screenprinted transfers to visually demonstrate the defined limitations. Research question 1 addressed whether the limitations documented in section 1.2 could be clarified and documented. I felt that demonstrating the limitations in an unbiased way in a body of tests was an important exercise as retrospective analysis of previous artwork suggested that tacit understanding of materials and processes had influenced previous artworks and had led to strategies being employed to disguise the anticipated limitations that would occur during the blowing process. Creating a body of demonstrations where the limitations were more clearly visible established the boundaries and created a reference point for further work.

Two demonstrations were undertaken and the making process was documented (See 3.5). The transfers containing the standardised image was screenprinted using the process detailed in 3.4. As seen in Figure 36, simply embedding a screenprinted transfer into a layer of glass ensured that there was minimal lateral or longitudinal distortion of the imagery beyond recognition (Limitation 1).

The image remained dense and there was minimal loss of clarity of the printed imagery resulting in deterioration of sharpness (Limitation 2 and Limitation 3). On this occasion there were no problems with compatibility. Applying printed imagery once the form has been blown or simply embedding it in a gather of glass without significant inflation is a process used by artists to ensure that their imagery is not significantly altered.

The second demonstration produced visible evidence of the problems that occur once printed transfers are embedded and the form is blown by approximately one hundred percent. It also clarified that certain components were affected in different ways.

Stretching of the imagery was immediately obvious and although each component underwent stretch, the most unacceptable component following inflation was the universally recognised figure that was stretched beyond recognition and therefore deemed unacceptable. The horizontal lines, vertical lines, the dense areas of colour were altered but remained acceptable. The text was placed at the top and the bottom of the form and, although all the text remained readable, there was more obvious distortion of the text at the top of the form compared to the text at the bottom of the form. Distortion of the imagery was again clearly seen and similarly some components were affected more than others. The horizontal and vertical lines and the universally recognised figure were more obviously affected and therefore deemed unacceptable. This was a finding in my own artwork. For example in ‘Colour me a Rainbow’ (See Figure 29) the patterned imagery had stretched and distorted but it had also added interest and movement and therefore did not affect the decorative appearance of the artwork.

The most disappointing finding to me was in relation to density. All of the components had faded. With the universally recognised figure, the fading was immediately obvious and it was inconsistent. This was a finding in previous practice and was the limitation that I personally found most unacceptable in previous artwork. For example in ‘Forgive me Father for I have Sinned” (Figure 31) the images were significantly faded in comparison to the original printed imagery (Figure 32)

Visually documenting the results of these demonstrations acts a guide to other artists/students who embed screenprinted imagery into blown glass forms. Review of the literature had shown that this information did not previously exist. If artists are aware of the limitations, they can take steps to overcome the problem. This knowledge could be used in the design stage of the artwork and it could assist the artist in improving their practice by highlighting the importance of choosing appropriate imagery, an appropriate form and the appropriate size/shape embryo etc.

This will reduce costs from wasted work where the decorative potential is vitiated and the work becomes unacceptable for sale or for exhibition purposes. Wasted work ultimately has an impact on the viability of a studio and it is an important consideration for a glassmaker. Glassblowing is an energy intensive process in terms of both costs of equipment and materials. Minimising waste is a small step in reducing the environmental impact on glassmaking as a process for contemporary art.

4. The development of creative print inspired glass processes

This chapter relates to aim and objective 2 of the research - to develop and document creative methods of working with glass by drawing inspiration from existing printmaking techniques and adapting them for use in the decoration of blown glass forms. Five creative print inspired methods for the decoration of blown glass forms were explored. A further two processes were explored in relation to additional technologies. Each method was introduced and a set of questions formulated to structure the testing. A hypothesis was given followed by a description of how each process was carried out. The results were documented using photographs and a conclusion drawn on whether the creative methods overcame any of the limitations. Each process was assessed in terms of visual quality.

4.1 Process 1 – Screenprinting glass powder to create a water-slide transfer

In previous practice a water-slide transfer was produced by mixing a solvent based medium with under-glaze enamel that was then screenprinted on to pre-covercoated transfer paper. Occasionally when applying this type of transfer to a pre-blown embryo form and subsequently embedding the transfer into layers of hot Gaffer glass, cracks appeared in the artwork. Although cracking could have occurred for several reasons such as problems with the lehr cycle or colour compatibility issues, it was thought that the incompatibility of the under-glaze ceramic enamel with Gaffer glass could have contributed to the cracking. It was hypothesised that substituting under-glaze ceramic enamel for Gaffer glass powder would theoretically ensure total compatibility of the printed transfer with the glass form and prevent cracking occurring.

The following questions were formulated as a starting point for experimentation into this process:

1. Can Gaffer glass powder be screenprinted to create a water-slide transfer?
2. If successful, can this transfer be applied to a pre-blown embryo form and embedded into layers of blown glass?

My hypothesis was that it would be possible to print a water-slide transfer using Gaffer powder mixed with solvent based medium screenprinted onto U-Wet transfer paper. This transfer could be applied to a pre-blown embryo form and encased into layers of hot glass. It was felt that, if total compatibility could be achieved, there would be no problem with the artwork cracking. An anticipated problem with this process was that the density of the transfer could be compromised due to the increase in particle size of Gaffer glass powder compared to the particle size of under-glaze enamel.

The starting point of this demonstration was to determine what sized mesh screen would allow the Gaffer glass powder to pass through effectively. Gaffer glass powder was applied and pushed through the mesh of six different sized screens using a squeegee. The screen sizes used were 120t, 90t, 70t, 54t, 34t, 9t. The screens that allowed the Gaffer powder to pass through were coated with light sensitive emulsion and exposed onto a light box with a 10 cm squared lace pattern. Black Gaffer glass powder was mixed with a solvent-based screenprinting medium. The mixture was applied to the screen at the bottom of the image. U-Wet transfer paper was placed under the screen and the image was flooded and then printed. The transfer was removed and allowed to dry fully. Each of the different sized mesh transfers were examined to see if they printed successfully and to assess whether any of the detail in the imagery had been compromised due to the coarseness of the mesh. Figure 37 shows the screenprinted transfer.

Figure 37 Screenprinted transfer, printed with glass powder through a through a 34t mesh screen 10 cm x10 cm.

Figure 38 Screenprinted glass transfer applied to blown glass embryo – 14 cm x 7 cm

The transfer was applied to the glass embryo by soaking it in a dish of water (Figure 38). This allowed the clear film layer of the transfer holding the printed imagery to lift away from the paper-backing sheet. The transfer was removed from the water before it floated completely away from the backing sheet. The transfer slid from the paper backing onto the surface of the embryo with the printed side of the transfer being on the outer surface of the glass embryo.

The transfer was carefully positioned and smoothed onto the surface of the embryo. Excess water was dabbed away with a soft cloth. Once the transfer had dried out, the glass embryo was placed into a top-loading kiln.

Figure 39 Screenprinted glass transfer fired onto blown glass embryo on the end of a blowing iron – 14 cm x 7 cm

The temperature was raised slowly (approximately 40ºc per hour) until it reached 560ºc (Figure 39). A collar was prepared on a blowing iron and this was used to pick the embryo out of the top-loading kiln. To fire the image from the transfer to the surface of the embryo, the embryo was reheated in the glory hole. It was then encased in a layer of hot glass, shaped, and blown into a simple vessel form (Figure 40).

Figure 40 Screenprinted glass powder transfer embedded into layers of a blown glass form

The artwork was observed and the results documented.

Table 6 – Table showing the performance of novel process 1 in relation to the limitations documented in 1.2.

Limitation	**Performance of limitation**
Stretch and distortion	The stretching and distortion of the image was not improved using this process. This is because the method of application was the same as applying a printed transfer and the process of embedding was also the same.
Density	The density of the imagery was not improved using this process.
Detail	The detail of the imagery was not improved using this process but was equal to detail achieved through using a screenprinted transfer printed with ceramic enamel.
Compatibility	This process ensured full compatibility of image and transfer by substituting the under-glaze ceramic enamel for Gaffer glass powder. The coefficient value of both the object and image were now the same.
Health and safety	Health and safety was not improved using this process. This is because solvent-based medium was still used to print the transfer.
Available technical information	No technical information relating to screenprinted transfer with Gaffer glass powder was identified.

Process 1 was an attempt to address the limitation of compatibility and an attempt to overcome the issues of cracking previously experienced. The demonstrations confirmed that it was possible to print a water-slide transfer using Gaffer glass powder mixed with solvent based printing medium.

Observations of the transfers post-printing indicated that the optimum size mesh for printing a Gaffer glass transfer was between 9t and 34t. Observation of the transfer post-printing indicated that potential problems could have been encountered during the application of the transfer to the embryo. This was due to the particle size of Gaffer glass being larger than the particle size of the solvent-based printing material. This resulted in the Gaffer glass transfer being more textured and the printed layer sitting more raised on the surface of the transfer paper. As a result, the printed image could have easily rubbed off during handling and when the transfer was being applied to the embryo. This did not happen and the image remained intact during application.

Using a Gaffer glass transfer was successful as it allowed a longer period of working time on the embryo including the possibility of multiple heating in the glory hole prior to gathering over the embryo. This differs from transfers printed with solvent-based printing mediums where multiple reheating could cause burn out of the image. This is because the optimum firing temperature of the solvent based printing material is lower than the temperature of the glory hole.

4.2 Process 2 – Screenprinting glass powder to create a glass stencil for roll-up

This process arose as a response to working with a particular style of detailed imagery, namely patterned lace. The aim of this process was to create a screenprinted glass print made from Gaffer glass powder whilst bypassing the use of water-slide transfer paper. The glass print could then be transferred through the roll-up method onto to a pre-heated blown glass form and embedded into layers of blown glass. My interest in this process arose as a response to the research of printmaker Steve Brown (2006). Brown developed a system utilising a plotter cutter, which allowed him to cut complex stencils from sticky backed vinyl sheets, which he then applied to a coarse mesh screen.

He subsequently dusted glass powder through the mesh to form a powdered glass image directly onto the surface of the kiln shelf below it. Multiple layers of powder were built up to form a denser image. Brown recognised that once the powder reached a certain height, it required support. He subsequently developed a second step in the process where a reverse image of the vinyl previously used was cut and applied to the mesh but, instead of dusting glass powder through it, a powdered mould material was used. This acted as a support system for the glass powder during the application of the powdered layers and subsequent firing in the kiln in order to fuse the image into a solid stencil. Post-firing the mould material was dusted away.

The following questions were formulated as a starting point for experimentation:

1. Can Gaffer glass powder be screenprinted directly onto a kiln shelf and fired to create a glass print?

2. If successful can this glass print be pre-heated and rolled-up into a blown glass form and embedded into layers of blown glass?

As process 1 and the work of Brown had demonstrated the possibility of directly screenprinting glass powder through a mesh screen, the hypothesis was that it would be possible to screenprint directly onto a kiln shelf using Gaffer glass powder. To ensure that the screenprinted glass powder fused together adequately but did not distort, it was deemed necessary to identify the correct firing temperature. A 35t (threads per cm) mesh screen was coated and exposed with a 10 cm square lace pattern and a kiln shelf was prepared by cutting a square of thin fire paper to cover the shelf. This acted as a release for the glass so that it did not stick to the shelf.

The screen was placed on top of the kiln shelf taking into account the distance between the mesh of the screen and the surface of the kiln shelf. To prevent the printed glass powder smudging, a distance of approximately 1 cm was used as it was vital that the mesh of the screen did not make contact with the kiln shelf. Glass powder was placed onto the screen and a squeegee was used to push the glass powder through the screen.

Although the same printing motion used in the process of screenprinting was used, downward pressure was not needed to bring the mesh into contact with the kiln shelf as this would have smudged the Gaffer powder and compromised the image. Observations were made after printing one layer (one pull or push of the squeegee across the mesh of the screen) of glass powder although it was anticipated that one layer would not be dense enough to fuse the glass powder together during firing. Initial tests included printing 2 layers of powder, 4 layers of powder, 6 layers of powder and multiple layers of powder using up to three different colours. The tests were placed into the kiln and fired. Observations were made on whether the printed powder had formed a glass print, was the glass print good enough to be rolled-up and encased into layers of blown glass, how much detail did the image contain and had the imagery and glass print distorted?

Figure 41 Kathryn Wightman Screenprinted glass stencil pre and post firing 10 cm x 10 cm (each square)

Figure 41 (reading from top to bottom) shows 2 layers, 4 layers and 6 layers of printed glass powder. The stencils on the left show the printed glass powder pre-firing and the stencils on the right show the results post-firing. The 6 layer stencil is more substantial than the 2 layer stencil but there is greater detail in the 2 layer stencil. However, when removing the stencils from the kiln, the 2 layer stencil did not survive. When comparing the stencils pre and post-firing, there was evidence that some distortion of the stencil had occurred, particularly with the 6 layer stencil. This could have been caused by an inconsistency in the amount of powder in certain areas of the stencil as well as a top firing temperature that was too high.

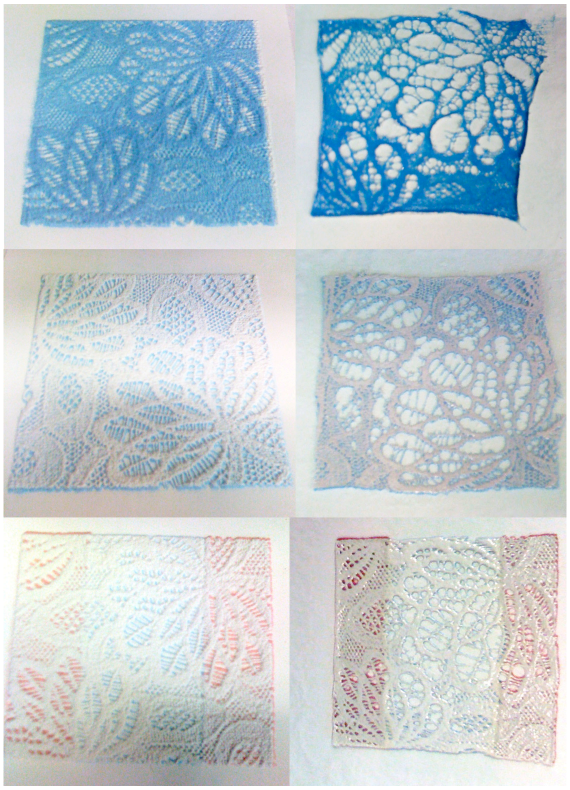


Figure 42 Multiple layers of coloured glass powder screenprinted on top of each other - each square measures 10 cm x 10 cm

Figure 42 shows multiple layers of coloured glass powder printed on top of each other. The stencils on the left show the printed glass powder pre-firing and the stencils on the right show the results post-firing. One issue with printing multiple layers of powder is concerned with registering the image when subsequently printing coloured glass powder. Problems with lining up the image exactly are evident in the stencil on the top left which appears blurred, as if there is a double image. These tests involved screenprinting the glass powder directly onto the kiln shelf. Due to the thickness of the shelf and limited amount of space in the kiln, my current process of registration was not possible and in this instance it was carried out by eye. A more precise method of registration would need to be considered if multiple coloured layers of printed powder were required.

Observations of initial tests identified a number of controllable variables that needed to undergo further testing in order to gain a greater understanding of the process. The controllable variables identified were: the required distance between the kiln shelf and the mesh of the screen, the optimum number of screenprinted glass powder layers and the optimum firing temperature of the screenprinted powder layers.

Further testing to determine the required distance between the kiln shelf and the screen involved two sets of testing one using black glass powder and one using white glass powder. The screen was raised up from the kiln shelf at 2 mm increases until it reached a distance of 10 mm. The optimum distance recorded was 6 mm.

Further testing to determine the optimum number of printed layers involved two sets of testing - one using black glass powder and one using white glass powder. Multiple layers of glass powder were printed through the screen directly onto the kiln shelf – 2 layers of printed glass powder, 4 layers of printed glass powder, 6 layers of printed glass powder, 8 layers of printed glass powder, 10 layers of printed glass powder. The glass powder was rubbed through the screen with the hand rather than a squeegee. The screenprinted layer tests were fired in kiln 19. The kiln cycle used to fire the layer tests was:

222°c per hr to 730°c for 10 min

222°c per hr to 483°c for 60 min

End

The following two tables visually demonstrate the results of the of the screenprinted glass layer tests and include pre and post fired imagery.

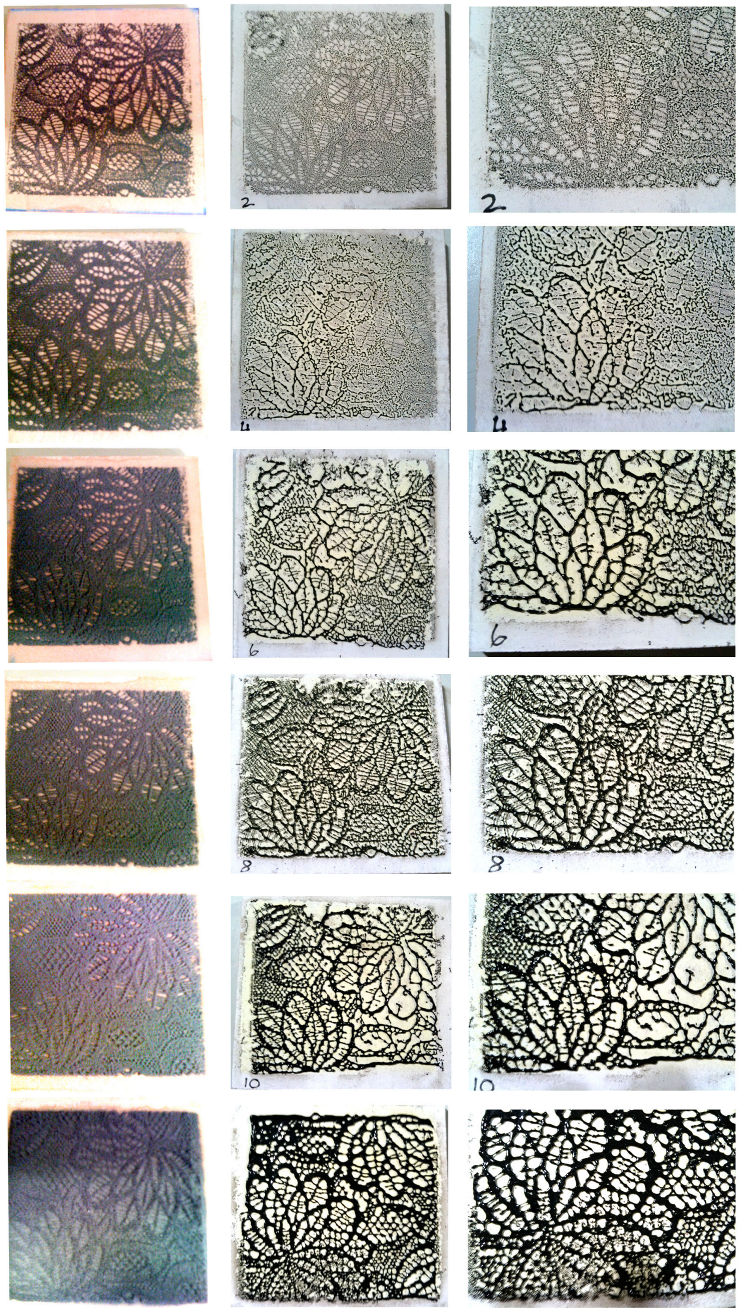


Figure 43 Screenprinted layers test, with black glass powder, pre and post-firing - each square measures 10 cm x 10 cm

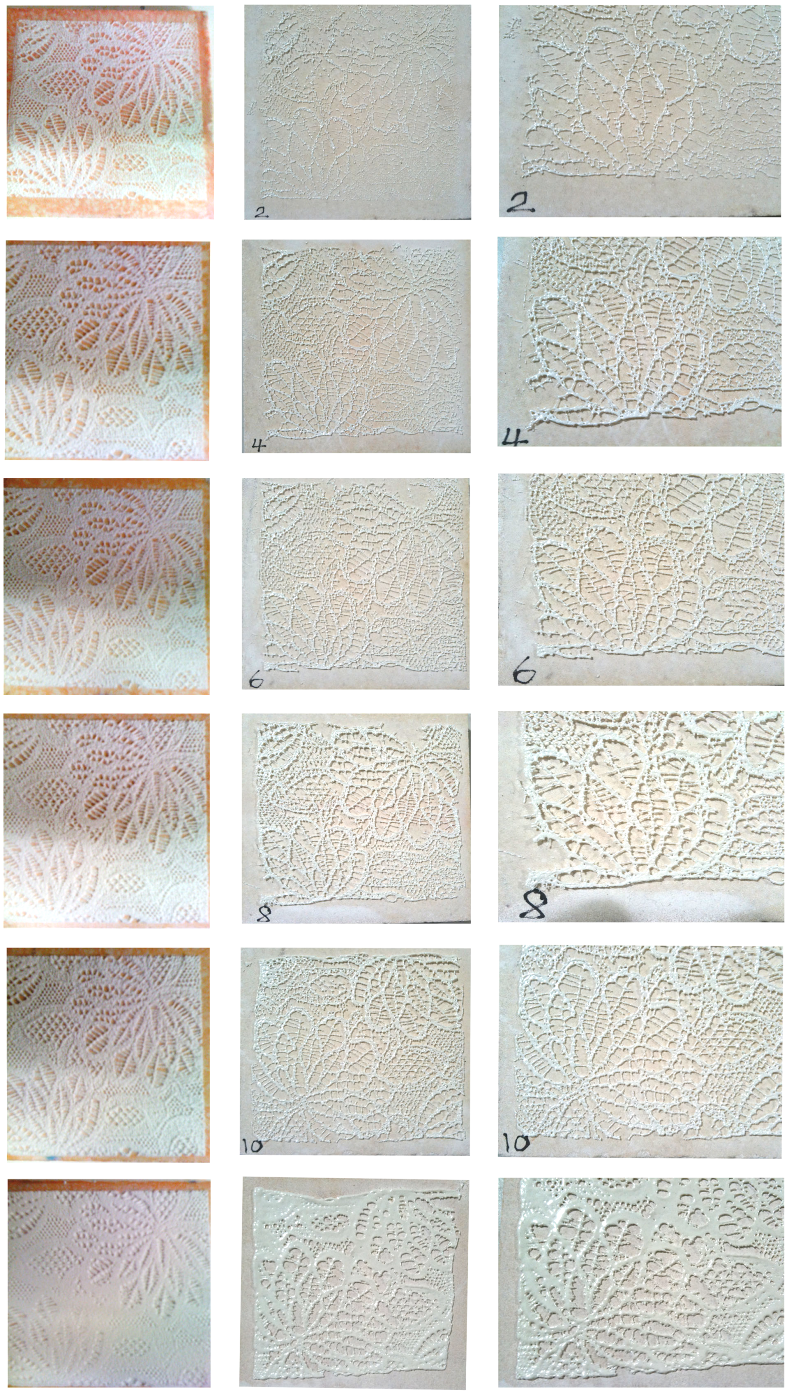


Figure 44 Screenprinted layers test with white glass powder, pre and post-firing - each square measures 10 cm x 10 cm

Figure 43 and Figure 44 demonstrates that 10 layers of printed glass powder created the densest glass print using both black and white glass. 2 layers of printed glass powder (both black and white) produced glass prints that could not be used as the contours of the pattern had deteriorated during the fusing cycle. The glass prints could not be removed from the kiln shelf in one piece. 4 layers of printed glass powder (both black and white) again produced glass prints that could not be used as the contours of the pattern had pulled apart in the fusing cycle. The glass prints were still unable to be removed from the kiln shelf in one piece. When comparing the black 4 layer glass print to the white 4 layer glass print, it was noticed that the white glass print, although still unusable, was the densest. Both 6 and 8 layers of printed glass powder (both black and white) produced glass prints that could be removed from the kiln shelf in one piece. However, the finer detailed parts of the lace did not fuse together, creating unacceptable gaps in the print. Again the white glass prints were denser than the black glass prints. 10 layers of printed glass powder created a detailed glass print that could be removed in one piece from the kiln shelf. The final row of images in both tables show the results of the glass powder rubbed through the screen by hand rather than printing with a squeegee. Pre-firing none of the holes in the lace pattern could be seen. Post-firing the holes could be seen, due to the powder contracting during fusing. The intricate detail of the lace was compromised when the squeegee was not used. The white glass print distorted during firing. This was due to uneven amounts of powder deposited in different areas of the image.

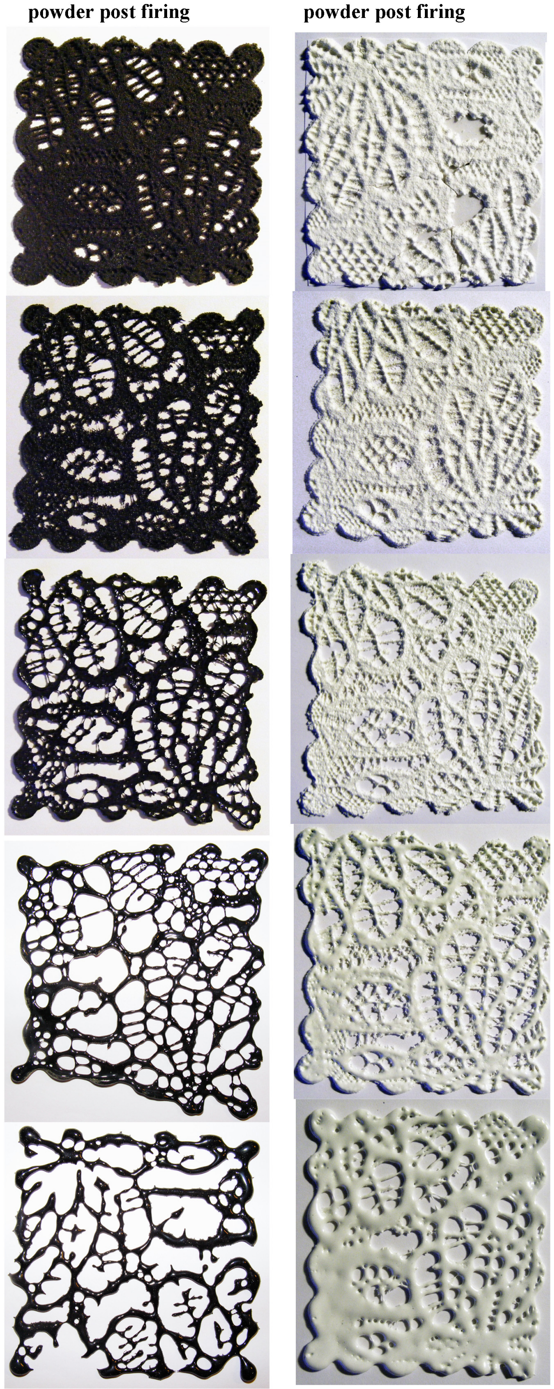
Further testing to determine the optimum firing temperature for fusing the powdered glass together involved two sets of tests carried out using black and white glass powder. Both black and white glass powders were printed then fired through a range of firing cycles in order to establish an optimum firing temperature.

All of the temperature tests were created using the following parameters: A screen with a mesh size of 34t was exposed with a 10 cm squared lace image. 14 layers of both black and white Gaffer glass powder were printed directly onto a batt washed kiln shelf. The distance between the surface of the kiln shelf and the mesh of the screen was approximately 6 mm.

Each test was placed into the kiln and fired individually to the required temperature. All of the temperature tests were fired in the same kiln (kiln 18). The following table visually demonstrates the results post firing.

Black screenprinted glass powder post firing

White screenprinted glass powder post firing



400°c per hr to 650°c for 10 min
400°c per hr to 510°c for 60 min

400°c per hr to 690°c for 10 min
400°c per hr to 510°c for 60 min

400°c per hr to 730°c for 10 min
400°c per hr to 510°c for 60 min

400°c per hr to 770°c for 10 min
400°c per hr to 510°c for 60 min

400°c per hr to 804°c for 10 min
400°c per hr to 510°c for 60 min

Figure 45 Screenprinted layers test - black and white glass powder, post-firing - each square measures 10 cm x 10 cm

Figure 45 demonstrates that with every firing cycle the black powder reacted differently to the white powder at the same temperature. The black powder absorbed more heat, resulting in a more melted appearance. A firing temperature of 650ºc produced a print that still looked powdery and it was brittle to handle, resulting in breakages in the white stencil. The print did not melt enough to reveal the gaps in the lace pattern. At a firing temperature of 690ºc, although gaps in the lace pattern began to appear, these were minimal in the white print compared to the black print. The prints were easier to handle although still slightly brittle. At a firing temperature of 730ºc the gaps in the lace pattern were clearly visible and the prints were a good representation of the original lace patterned image. At a firing temperature of 770ºc, the gaps in the print had become too open, resulting in a less structured print. The surface of the print had become glossy and smooth in areas, resulting in loss of texture. In the black print, distortion of the print occurred due to an uneven thickness of powder in certain areas. At a firing temperature of 804ºc the prints became unusable. The structure of the black print was completely compromised. The white print remained more structured but the definition in the lace was lost. It was concluded from this test that the optimum firing temperature for black powder was between 690ºc and 730ºc. For the white powder the optimum firing temperature was approximately 730ºc.

Once the optimum conditions for producing a glass print had been determined and a suitable glass print had been created, further experimentation was undertaken in the hot studio to combine this approach with blown glass. Both black and white lace glass prints were printed. With the black glass print the distance of the screen mesh to the surface of the kiln shelf was 4 mm. This was 6 mm with the white glass print. The number of layers of glass powder printed through the surface of the screen for both black and white powder was 10 layers.

The kiln cycle used to fire the black screenprinted powder was:

400°c per hr to 700°c for 10 minutes
400°c per hour to 510°c for 60 minutes
End

The kiln cycle used to fire the white screenprinted powder was:

400°c per hr to 740°c for 10 minutes

400°c per hour to 510°c for 60 minutes

End

Figure 46 shows both black and white glass powder printed with the optimum number of layers and fired at the optimum temperature.

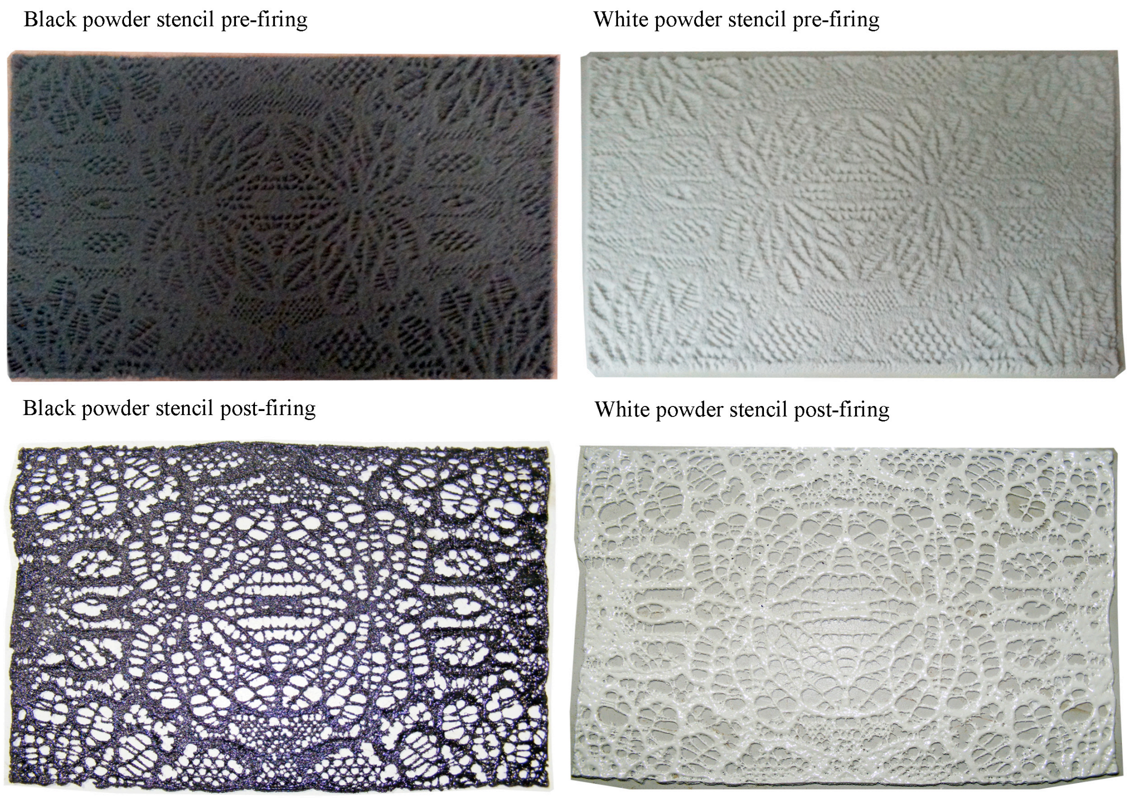


Figure 46 Black and white glass stencil pre and post firing - 19.5 cm x 13.5 cm

Observations of both the black and white powder prior to firing show that the pattern can be clearly seen although none of the gaps in the lace are visible at this stage. Post-firing the gaps in the lace were revealed and the structure of the lace pattern was maintained. Both tests were deemed successful. Figure 47 documents the production stages of combining the process with blown glass.

In preparation for pick up both black and white printed glass stencils were placed face down onto a batt washed kiln shelf. The shelves were placed on a prop inside the lehr. The temperature of the lehr was gradually brought up 50 degrees per hour until it reached 560 degrees celsius.

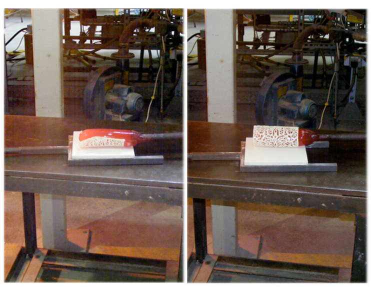
A small piece of black glassblowing colour was picked up on the end of the blowing iron. The colour was melted in the glory hole and shaped using the jacks. A small bubble was then blown into the colour.

The colured bubble was then cooled down in preparation for gathering more glass. The bubble was inserted into the furnace and a layer of molten glass was added. This was then shaped first using a wooden block and then a newspaper paper pad.

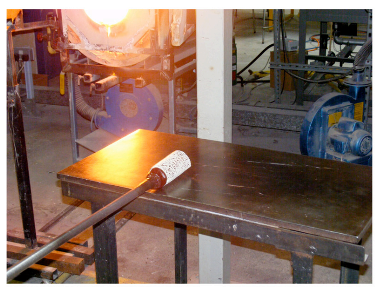
The bubble was blown to the required size. The length and width of the glass stencil had been calibrated with the length and circumference of the bubble. Further shaping was undertaken to ensure the bubble was straight sided.

Whilst the bubble was being prepared the pre-heated stencil was picked up using a pastorelli.

The pastorelli was carried straigh to the glory hole where the glass stencil was heated. The stencil did not require much heating in the glory hole due to its thickness. The stencil was removed from the glory hole when its edges became softer in appearance.



Whilst the stencil was being heated the bubble was also being heated so that it was just glowing red. The pastorelli was then placed onto the marver and the stencil was touched down onto the stencil then rolled in order to stick it to the surface of the bubble.



The stencil and bubble were heated in the glory hole then rolled on the surface of the marver to ensure the stencil was attached to the bubble.

A cut line was made in the bubble using a pair of jacks.

The bubble was then bench blown and shaped. The base was flattened and a punty was applied to transfer it to another iron so the rim could be opened out.

The rim was opened out and shaped using the jacks.

Once happy with the shape of the piece it was given a final reheat. The punty was chipped with a knife and the piece was removed and placed in the lehr where it was cooled down gradually.

Figure 48 Black and white glass powder integrated into blown glass – 15 cm x 8 cm.

Table 7 Table showing the performance of novel process 2 in relation to the limitations documented in 1.2

Limitation	Performance findings
Stretch and distortion	The stretching and distortion of the image was not improved using this process.
Density	The density of the image was improved using this process as the printed imagery was not supported by a substrate but existed as a glass print that was built up of multiple layers of powdered glass.
Detail	The detail of the imagery was not improved using this process but was equal to detail achieved through using a screenprinted transfer. Imagery with closed contours would be required when using this process.
Compatibility	This process ensured full compatibility of image and glass object by substituting the under-glaze ceramic enamel for Gaffer glass powder. The coefficient value of both the object and image were now the same.
Health and safety	Health and safety was improved using this process, as a solvent based printing medium was not needed.
Available technical information	Limited technical information related to the use of this process for glassmaking. No technical information on combining this process with blown glass.

Process 2 was an attempt to address the limitation of compatibility and attempted to overcome the issues of loss of density previously experienced. This process successfully produced a blown glass object with imagery that had not faded and it ensured that the density of a screenprinted glass print was greater than that of a screenprinted transfer. Unfortunately the detail of the glass print was compromised during the blowing process.

This was because, prior to the print being rolled onto the side of the blown bubble, it had to be heated in the glory hole to a temperature where the glass became malleable. This temperature was greater than the optimum temperature for fusing the print and the result was that the definition in the lace pattern was compromised (see above temperature tests). With this process, the compatibility of image and glass object are the same as both are created using Gaffer glass. One benefit of using this process is that the use of a solvent-based printing medium is eliminated.

It was concluded from these tests that, although the process was not suitable for use with blown glass, the two-dimensional printed sheets had potential for further development. An area of further research identified during this process was the use of vinyl cut stencils as an alternative method for coating coarse mesh screens. The rationale for this approach is to eliminate the problem encountered when attempting to coat a coarse mesh screen with photo-sensitive emulsion. Difficulty arose as the emulsion was not trapped by the mesh, resulting in an uneven layer of emulsion. If this substitution was successful, it would allow a coarser mesh screen to be used resulting in a denser glass print.

4.3 Process 3 – Screenprinting glass powder onto sheet glass to create a roll-up sheet

This process arose as a response to the previous screenprinting process. As the glass print created was fragile, it was felt that screenprinting Bullseye glass powder onto a glass sheet would act as backing and provide more stability. It was anticipated that producing a glass backing sheet would create a canvas particularly suited to the roll-up process. Bullseye glass was used in this process because, unlike Gaffer glass, it is readily available in powder, sheet and furnace batch.

Brown (2006) initially used a glass sheet as a ground for his dusted imagery but later disregarded the sheet in favor of forming a stencil. His reasons for this were linked to the relationship between the image and the form; he felt the rectangular sheet format was limiting and he was essentially producing pictures, something unfamiliar to his practice.

The following questions were formulated as a starting point for experimentation into this process.

1. Can Bullseye glass powder be screenprinted directly onto Bullseye sheet glass and fired to create a patterned sheet?

2. If successful can this patterned sheet be pre-heated, rolled up and encased in layers of blown glass?

As previous testing had shown that it was possible to print Gaffer glass powder directly onto a kiln shelf, it was anticipated that it would be possible to print Bullseye glass powder directly onto a sheet of Bullseye glass. Again the correct firing temperature was important to ensure the powder and the sheet fused together but the textured pattern created by the powder did not disappear. A 35t (threads per cm) mesh screen was coated and exposed with a 10 cm squared lace pattern and a kiln shelf was prepared by cutting a square of thin fire paper to cover the shelf. This acted as a release for the glass so that it did not stick to the shelf. A 10 cm square sheet of 3 mm Bullseye sheet glass was cut. The screen was placed over the square of sheet glass, registering the pattern so that it printed onto the surface of the sheet glass. A distance of approximately 6 mm between the mesh of the screen and the surface of sheet glass was needed.

Bullseye glass powder was placed onto the screen and a squeegee was used to push it through the surface using the same motion as screenprinting. Unlike screenprinting, downward pressure was not needed to bring the mesh into contact with the kiln shelf as this would have smudged the glass powder and destroyed the image. Observations were made after printing one layer of powder. It was thought that, although one layer of powder would fuse to the sheet glass, the image would not be dense enough.

Initial tests included printing 2 layers of powder, 4 layers of powder and 6 layers of black powder on to 3 mm opaque white sheet glass. A variety of other colours were also printed onto a range of transparent and opaque backgrounds. The tests were placed into the kiln and fired. Observations were made on whether the tests survived: Did the printed powder fuse to the surface of the sheet glass? Was the sheet good enough to be rolled-up and embedded into layers of blown glass? How much detail did the image contain? Had the imagery distorted?

Figure 49 shows the initial tests post-firing.

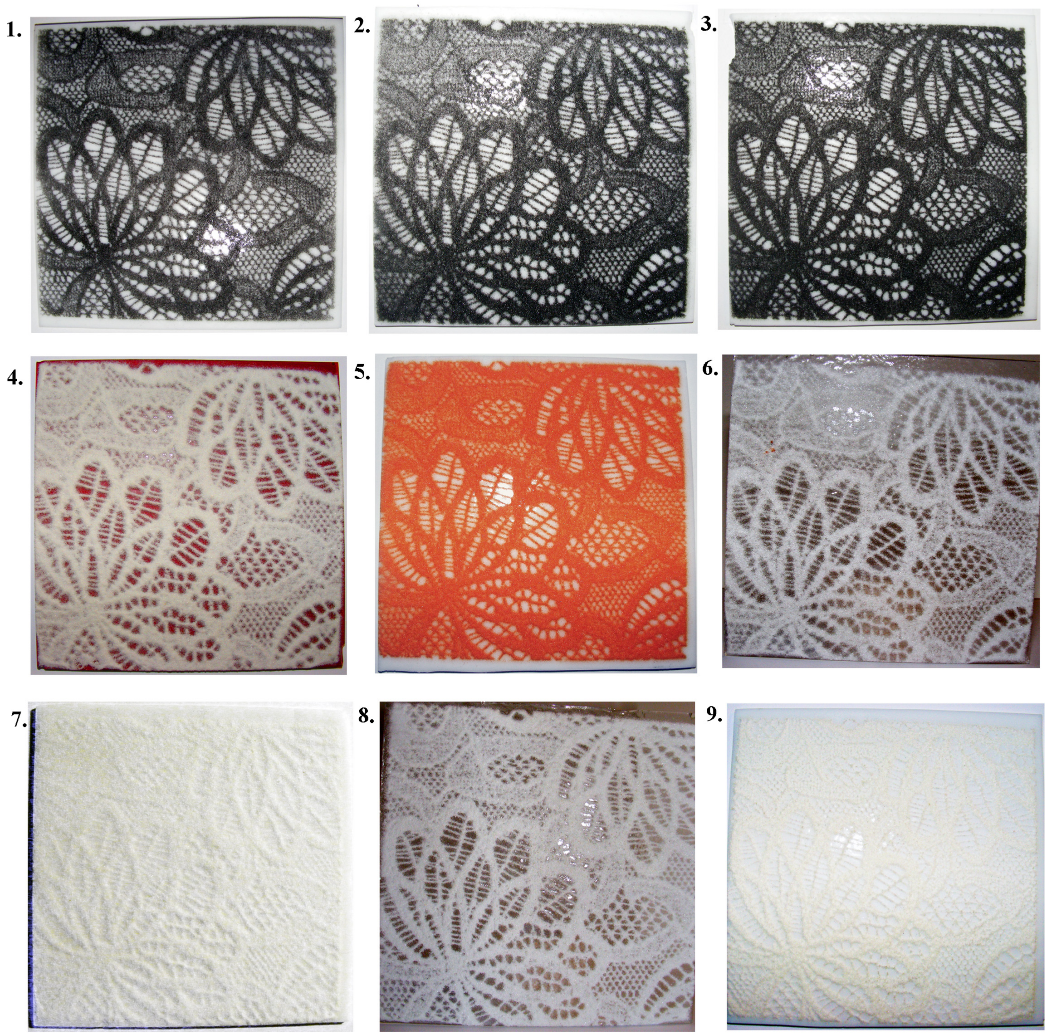


Figure 49 Screenprinted powder on sheet glass post-firing - each square measures 10 cm x 10 cm.

1. 2 layers of black glass powder on 3mm opaque white sheet glass
2. 4 layers of black glass powder on 3mm opaque white sheet glass
3. 6 layers of black glass powder on 3mm opaque white sheet glass
4. 6 layers of red powder on 3mm opaque white sheet glass
5. 6 layers of white powder on 3mm transparent fuchsia sheet glass
6. 6 layers of white powder on 3mm clear sheet glass
7. 6 layers of white powder on 3mm opaque white sheet glass
8. 6 layers of vanilla powder on 3mm clear sheet glass
9. 6 layers of vanilla powder on 3mm opaque white sheet glass

The initial tests demonstrated that it was possible to fuse Bullseye glass powder to Bullseye sheet glass. Out of the first three tests using 2, 4 and 6 layers of black glass powder, test 3 (6 layers) created the densest imagery although all tests were deemed successful. All of the nine tests created a two-dimensional sheet that was capable of being rolled-up into a three-dimensional form. The detail of the lace imagery was not compromised in any of the tests. The introduction of a backing sheet to the printed glass powder ensured that the imagery did not distort during firing. However, it was noted that, if a striking colour such as red was to be used, the firing temperature would not be high enough to strike the colour. Although the use of white powder on a white background did not produce a sheet where the imagery was clearly seen, the texture created using this process produced imagery that had a subtle but interesting visual aesthetic.

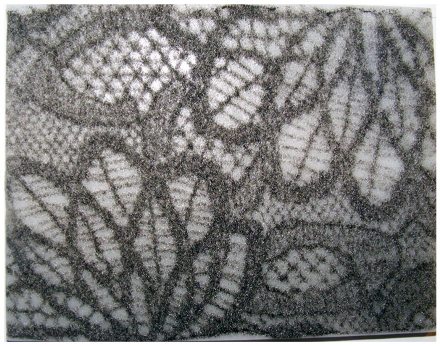
Carrying out and observing the initial tests identified a number of controllable variables that needed to be subjected to further testing in order to gain a greater understanding of the process. The controllable variables identified were: the required distance between the sheet glass and the mesh of the screen, the optimum number of screenprinted glass powder layers and the optimum firing temperature of the screenprinted glass powder layers.

Further testing to determine the required distance between the kiln shelf and the screen involved two sets of testing one using black glass powder and one using white glass powder. The screen was raised up from the surface of the sheet glass at 2 mm increases until it reached a distance of 10 mm. The optimum distance recorded was 6 mm.

Further testing to determine the optimum number of printed layers involved two sets of tests, one using black glass powder and one using white glass powder. All of the screenprinted glass powder layer tests were created using the following parameters: A screen with a mesh size of 34t was exposed with a 10 cm squared lace image. Specified amounts of layers were printed onto 4 mm white Bullseye sheet glass and included 2 layers of printed glass powder, 4 layers of printed glass powder, 6 layers of printed glass powder, 8 layers of printed glass powder, 10 layers of printed glass powder. The glass powder was also rubbed through the screen with the hand instead of squeegee. The distance between the surface of the sheet glass and the mesh of the screen was approx 6 mm.

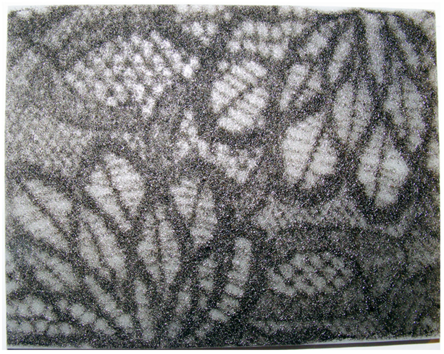
Each test was placed onto a batt washed kiln shelf and fired to the required temperature. The screenprinted layer tests were fired in kiln 19. The kiln cycle used to fire the layer tests was:
222°c per hr to 730°c for 10 min
222°c per hr to 483°c for 60 min
End

Figure 50 demonstrates the results of the black powder post-firing. Due to the lack of contrast between the white powder and the white sheet glass, it was not possible to obtain clear photographic evidence of the white glass powder temperature tests.



2 printed layers of black glass powder

8 printed layers of black glass powder



4 printed layers of black glass powder

10 printed layers of black glass powder

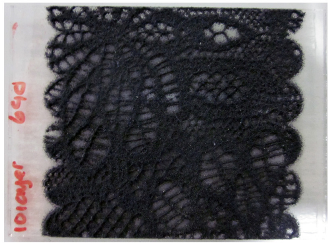
6 printed layers of black glass powder

black glass powder rubbed by hand through the surface of the screen

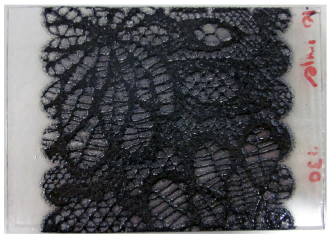
Figure 50 Screenprinted layers tests on sheet glass post -firing -each rectangle measures 10 cm x 7 cm.

The main observation with the screenprinted layer tests is that a 10 layer print created the most usable image in terms of density. The detail of the imagery marginally deteriorated as the number of layers was increased. However, the detail in the 10 layer print was acceptable for use. The print where the powder was rubbed through the surface of the screen resulted in a loss of detail in the imagery as well as uneven areas of powder. However, definition could still be seen from the texture created.

Two sets of temperature tests were carried out using black and white glass powder printed onto clear sheet glass. Both black and white glass powders were printed then fired through a range of firing cycles in order to determine the optimum firing temperature. All of the temperature tests were created using the following parameters: A screen with a mesh size of 34t was exposed with a 10cm squared lace image. 14 layers of both black and white Gaffer glass powder were printed directly onto a batt washed kiln shelf. The distance between the surface of the kiln shelf and the mesh of the screen was approximately 6mm. Each test was placed into the kiln and fired individually to the required temperature. All of the temperature tests were fired in the same kiln (kiln 18). The following table visually demonstrates the results post firing. Due to the lack of contrast between the white powder and the white sheet glass, it was not possible to obtain clear photographic evidence of the white glass powder temperature tests.



222°c per hr to 690°c for 10 min
222°c per hr to 483°c for 60 min



222°c per hr to 730°c for 10 min
222°c per hr to 483°c for 60 min

222°c per hr to 770°c for 10 min
222°c per hr to 483°c for 60 min

222°c per hr to 804°c for 10 min
222°c per hr to 483°c for 60 min

222°c per hr to 830°c for 10 min
222°c per hr to 483°c for 60 min

Figure 51 Screenprinted temperature tests on sheet glass post –firing each rectangle measures 10 cm x 7 cm.

Observations of the temperature tests (Figure 51) demonstrated that at 690ºc the screenprinted glass powder had a granulated matt appearance and it was rough to touch. At 730ºc the screenprinted glass powder had begun to melt together but the texture of the pattern was still visible.

At 770ºc the screenprinted glass powder was smoother in appearance with minimal texture. The surface of the powder was glossy. At 804ºc the screenprinted glass powder had melted into the surface of the sheet glass and no texture was visible. At 830ºc the sheet glass had begun to distort, resulting in loss of detail in the screenprinted imagery. Therefore the optimum temperature for firing multiple layers of screenprinted Bullseye glass powder is between 730ºc and 770ºc. This would vary according to how much texture is required in the artwork.

Once the optimum conditions for producing a glass print on sheet glass had been determined and a suitable print had been created, further experimentation was undertaken in the hot studio to combine this approach with blown glass. A sheet of 3 mm opaque white glass and a sheet of 3 mm clear glass were fused together prior to printing. This created a 6 mm sheet that was of a substantial thickness to withstand the roll up process. Two 6 mm sheets were created. A lace pattern was printed with black Bullseye glass powder onto both 6 mm sheets of glass. The distance of the screen mesh to the surface of the kiln shelf was 6 mm. The number of layers of glass powder printed through the surface of the screen was 14.

The kiln cycle used to fire the printed powder was:

222°c per hr to 710°c for 10 minutes

222°c per hour to 483°c for 90 minutes

End

Figure 52 demonstrates the sheets pre and post-firing.

Pre-firing

Post-firing

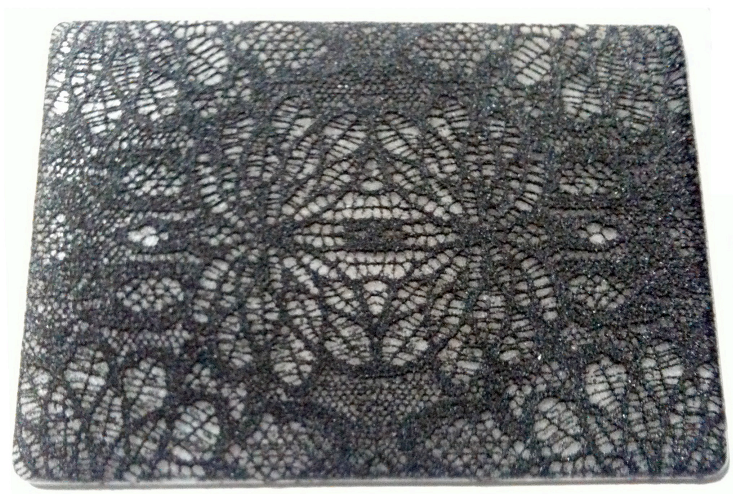


Figure 52 Screenprinted black Bullseye glass powder on pre fused white and clear sheet glass, pre and post-firing - each rectangle measures 20 cm x 12.5 cm

Observations of the black powder prior to firing show that the pattern of the lace imagery can be clearly seen although none of the gaps in the lace are visible at this stage. Post firing the gaps in the lace were revealed. The extent of the density of the imagery can be seen as the sheet has a textured appearance. Figure 53 demonstrate the production stages of combining the process with blown glass. Figure 54 shows the work created.

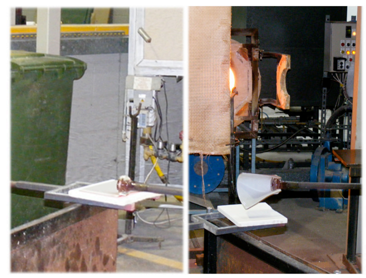
In preparation for pick up both printed sheets were placed on batt washed kiln shelves. One was placed pattern side up the other pattern side down. The shelves were placed on a prop inside the lehr. The temperature of the lehr was gradually brought up 50 degrees per hour until it reached 560 degrees celsius.

A collar was prepared on a blowing iron by taking a gather of glass from the furnace, blowing a bubble in it, then shaping the glass into a disc shape using the jacks. The diameter of the disc was calibrated in size to match up with the length of the sheets edge that was going to be rolled up.

Whilst the collar was being prepared the pre-heated sheet of printed glass was picked up from the lehr using a pastorelli.

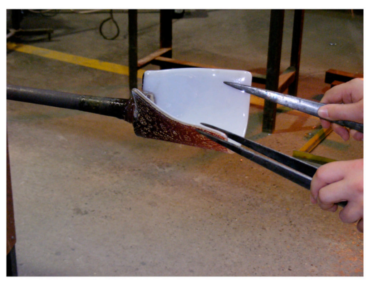
The pastorelli was carried straigh to the glory hole where the glass sheet was heated. Due to the thickness of the printed sheet multiple re heats in the glory hole were required.

To check how much heat and how evenly distributed the heat in the sheet was it was brought to the bench and the corners were lifted using the tweezers. If the corners were soft and bendy the panel was ready for roll up.

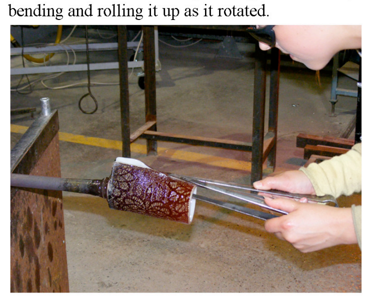


Whilst the sheet was being heated the collar was also re heated till it was just glowing red. The pastorelli was placed on the bench and the collar was touched down to stick it onto the sheet. The collar was then rolled along the edge of the sheet, bending and rolling it up as it rotated.

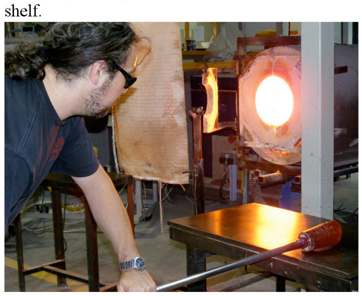
Once the pastorelli had been removed and the sheet had been flashed in the glory hole it was brought back to the bench and dusted using a newspaper pad. This was done to remove any of the dust picked up from the batt washed kiln shelf.



The edges of the sheet then had to be joined. Inbetween reheats the edges were sewn together.



The edges furthest away from the collar were joined first working back towrads the collar. The tweezers were used to grip the edges and touch them together. Finally the back edges were pressed against the collar. The sheet had been transformed into a cylindrical form.



To ensure the seam had fully sealed, further reheating and marvering was undertaken. Marvering also ensured everything was straight and the seam was flat.

The end of the cylinder was then sealed by creating a cut line with the jacks approximately 2cm from the edge of the cylinder.

The jacks were squeezed together so that the bubble became sealed. The end piece was then cooled down and knocked off by filing around it then gently tapping it with the file.

The sealed bubble was then blown up at the bench and a cut line was inserted with the jacks just off the end of the iron.

The base of the bubble was flattened using the flat handle of the jacks. The piece was now ready to be transferred onto a punty iron so that work could be carried out on the rim.

Once the piece had been transferred to the punty iron it was reheated in the glory hole so that the rim became workable. The blades of the jacks were inserted into the rim and upward pressure was applied to open out the rim.

To straighten out the sides of the form the blades of the jacks were also rested on the outer walls of the form.

The flat handle on the jacks was also used to ensure the sides wer straight.

Once happy with the form the piece was given a final reheat to even out the temperature. The punty was chipped around with a knife removed from the iron and placed in the lehr to cool down gradually.

Figure 54 Screenprinted black Bullseye glass powder on pre-fused white and clear sheet glass, rolled-up and blown into cup forms - each cup measures 11 cm x 8 cm x 8 cm.

Table 8 Table showing performance of novel process 3 in relation to the limitations documented in 1.2.

Limitation	**Performance of novel process 3**
Stretch and distortion	The stretching and distortion of the image was improved using the roll up process, although it should be noted that this may not be the case with a more complicated blown form.
Density	The density of the image was improved using this process as the printed imagery was built up of multiple layers of powdered glass.
Detail	The detail of the imagery was not improved using this process but was equal to detail achieved through using a screenprinted transfer.
Compatibility	This process ensured full compatibility of image and glass object by substituting the under-glaze ceramic enamel for Bullseye glass powder. The coefficient value of both the object and image were now the same.
Health and safety	Health and safety was improved using this process, as a solvent based printing medium was not needed.
Available technical information	Limited technical information related to the use of this process for glassmaking. No technical information on combining this process with blown glass.

In conclusion it was possible to create a blown glass form from Bullseye sheet glass screenprinted with Bullseye glass powder. This process was successful and it overcame the limitations in several areas. The density of the imagery was improved as the imagery was built up of multiple layers of screenprinted glass powder. By building up the layers of glass powder it was also possible to create textured as well as patterned sheets of glass. The amount of texture created was dependant upon the number of printed layers of glass powder as well as the temperature at which the glass powder was fired. However, this texture disappeared during integration with blown glass as the temperature required to make the glass sheet malleable for the roll-up process was greater than the temperature required to maintain the texture of the glass powder.

The detail of the imagery created using process 3 was equal to the detail created through the use of screenprinted transfers. If imagery with a varied colour palette was required, each colour would have to be printed separately and fired before the next colour was printed. This concept is the same as screenprinting where each colour has to be dry before the next colour is printed.

Similar to process 1 and process 2 there were no issues with compatibility and health and safety improved.

4.4 Process 4 – Hand-carving a plaster block to create a patterned roll-up sheet

The process of using a relief carved plaster block arose as a response to the previous screenprinted powdered sheet process (See Process 3). It was anticipated that a greater depth of patterned texture would be achieved through the forming of a glass sheet from a carved plaster mould. It was felt that this method would eliminate the reverse stencil used in Brown's process for building up the powdered mould material that supported the glass powder. The work of glass artist Philipa Beveridge (2002) was relevant to initial exploration of this method as she had similarly investigated the use of relief printmaking processes for integration with glass. Petrie (2006, p.71) described Beveridge's method for use with cast glass.

The first step involved cutting the image into the lino. Plaster moulds were then taken from the cut lino. Subsequent wax moulds were taken from the plaster and joined together using a blowtorch and modeling tools, to form a larger wax mould. A plaster/silica mould was taken from the wax and the wax melted out. The plaster/silica mould was filled with casting glass and fired in a kiln to form a textured block.

The following questions were formulated as a starting point for experimentation:

1. Can a plaster block be hand-carved in relief to create a mould into which Gaffer glass powder can be inlaid and fired to form a patterned glass sheet?

2. If successful can the Gaffer glass sheet then be pre-heated and rolled onto a blown glass form and encased in layers of blown glass?

The work of Beveridge had already demonstrated the possibility of forming moulds from relief printmaking processes to produce patterned, textured, two-dimensional glass surfaces. Process 3 had also demonstrated how it was possible to roll-up patterned, textured two-dimensional glass sheets to form three-dimensional glass forms. Based on this evidence, the hypothesis was, that it would be possible to create a relief patterned sheet of glass from a hand-carved plaster block that could be subsequently rolled-up and encased in layers of blown glass.

Figure 55 Repeat flower pattern hand carved into plaster block - 24 cm x 24 cm

Figure 56 Rubber silicon mould taken from plaster mould – 24 cm x 24 cm

In the initial testing a plaster block was created by constructing wooden dams into a square on top of a clean sheet of glass. The plaster was then poured into the dams. Once the plaster had set, the dams and sheet glass were removed. The use of sheet glass resulted in a smooth flat surface for carving. A simple repeat flower pattern was drawn onto the surface of the plaster block then carved into it using a metal scribe (Figure 55). A silicon rubber former was taken from the patterned surface in order to reproduce the pattern at a later date (Figure 56).

A plaster/molochite mould was taken from the silicon rubber former. The relief flowers in the mould were filled with black Gaffer glass powder by scraping a rubber kidney across the surface of the mould to infill the powder into the relief pattern. The excess powder was removed. To create a backing sheet of glass to support the flower pattern, a layer of white Gaffer glass powder was spread over the whole mould. The mould was placed into the kiln to fuse the glass powder into a glass sheet.

Figure 57 Kiln-formed glass sheet moulded from a hand-carved plaster mould - 24 cm x 24 cm.

Observations of the two-dimensional glass sheet post-firing revealed that it was possible to create a hand-carved relief plaster block into which Gaffer glass powder was inlaid and fired to form a patterned glass sheet. A noticeable feature in the sheet is the smudges of black powder around the edges of the pattern. These smudges are a result of the excess black powder not being entirely removed from the plaster mould during infilling. The patterned flowers post-firing were not as textured as the relief in the surface of the plaster/molochite mould. This was due to shrinkage of both the glass and the mould during firing. This shrinkage had also affected the edges of the pattern meaning that they would not join correctly when rolled-up. Jagged needle-point edges created in the kiln-forming process would also affect the neatness of the seam line created with the roll-up process. The backing layer of white glass was inconsistent in thickness (thick in the middle and thin at the edges). This inconsistency had the potential to cause problems during the roll-up and blowing process.

The sheet was taken in to the hot shop, rolled onto a bubble form, gathered over and blown into a vessel form.

Figure 58 Front view of blown glass vessel created using a rolled up glass sheet formed from hand-carving a plaster mould - 30 cm x 21 cm x 21 cm

Figure 59 Back view of blown glass vessel created using a rolled up glass sheet formed from hand-carving a plaster mould - 30 cm x 21cm x 21cm

Table 9 Table showing performance of novel process 4 in relation to the limitations documented in 1.2

Limitation	**Performance of novel process 4**
Stretch and distortion	The stretching and distortion of the image was not improved using this process.
Density	The density of the image was improved using this process as the imagery was taken from the relief surface of the hand-carved plaster mould.
Detail	The detail of the imagery was not improved using this process and relied upon the hand-carving skill of the artist.
Compatibility	This process ensured full compatibility of image and glass object by substituting the under-glaze ceramic enamel for Gaffer glass powder. The coefficient value of both the object and image were now the same.
Health and safety	Health and safety was improved using this process, as a solvent based printing medium was not needed.
Available technical information	Limited technical information related to the use of this process for glassmaking. No technical information on combining this process with blown glass.

Process 4 was an attempt to create denser imagery than the imagery created using process 3. The denser the imagery created, the greater the possibility of inflating the form without the imagery losing density to unacceptable levels. The introduction of the plaster mould was introduced to facilitate this attempt. On reflection, even though the process was successful in creating denser imagery, the ability to create detailed imagery was compromised. This was because the hand-drawing/carving aspect of process 4 was reliant upon the skill of the artist. In process 3 both hand-drawn and computer generated imagery can be used with screenprinting, meaning less of an emphasis is placed on the drawing/carving skills of the artist. Production time was also an issue with this process as the time taken to hand-draw/carve the imagery into the block was considerably longer than the time taken to screenprint the imagery in process 3.

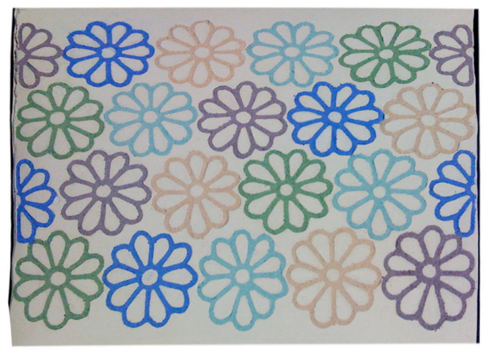
The image on the back of the form post roll-up highlights the issue of lining up the pattern during the blowing process. The seam line that runs down the form detracts from the repeat flower pattern used in professional practice. This seam line would need to be refined if this process was to be used. One potential method of doing this would be to set the pattern approximately 1 cm in from each edge of the plaster mould. After the two-dimensional glass sheet has been kiln-formed, the excess glass could be removed using cold working techniques. Cold working the edges of the glass sheet would also eliminate the jagged, needlepoint edges created in the kiln-forming process.

One benefit with this process is that the compatibility of image and glass object are the same as both are created using Gaffer glass. In addition this process eliminates the need for a solvent-based printing medium. Another benefit of process 4 could be the potential it offers to create imagery made up of a variety of colours. Instead of using one coloured glass powder to infill the relief pattern in the mould, a variety of coloured glass powders could be used. Using a varied coloured palette when screenprinting glass powder (Process 3) would involve firing the glass after each layer has been printed. This would increase production time as well as the risk of the glass cracking and breaking due to stress in the material. In process 4, no additional firings are required but the artist would need time and patience when infilling the glass powder into the mould. The use of a varied coloured palette was investigated.

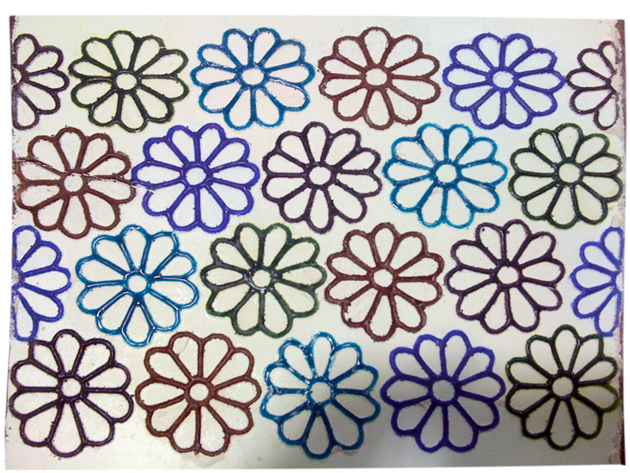
The two-dimensional relief patterned glass sheets were formed using the same process as the initial tests with this process. The following images demonstrate how it was possible to form a two-dimensional patterned glass sheet from a relief plaster mould in-filled with a variety of coloured Gaffer glass powders (Figure 60)

Pre-fired plaster/molochite mould infilled with five opaque glass powders

Pre-fired plaster/molochite mould infilled with five transparent glass powders



Post-fired glass sheet with opaque glass powder flowers, fired from plaster/ molochite mould.



Post-fired glass sheet with transparent glass powder flowers, fired from plaster/ molochite mould

Figure 60 Hand- carved plaster moulds in-filled a variety of coloured glass powders and kiln-formed glass sheets moulded from a hand carved plaster moulds - 24 cm x 24 cm.

One of the multiple coloured two-dimensional glass sheets was taken into the hot shop, rolled-up onto a bubble form, gathered over and blown into a three-dimensional form.

Figure 61 Front view of blown glass vessel created using multiple colour glass sheet formed from hand-carving a plaster mould – 30 cm x 21 cm x 21 cm.

Figure 62 Back view of blown glass vessel created using multiple colour glass sheet formed from hand-carving a plaster mould – 30 cm x 21 cm x 21cm.

Observations of the tests using a varied coloured palette demonstrate that it is possible to create a multiple coloured glass sheet from a hand-carved plaster mould. However, it takes time and patience to in-fill the different coloured glass powders into the relief pattern in the plaster mould.

An area for further development related to process 4, was refining the uneven thickness and shrinking of the backing sheet containing the pattern. It was anticipated that a stencil with a cut out the same size as the required sheet could be in-filled with glass powder to ensure the same depth was used across the whole surface. To determine the optimum depth of the stencil, a series of tests were devised. Tests involved cutting 5 cm square cut outs from different thickness of 10 cm square sheets of Perspex (Figure 63).

The Perspex used was 2 mm, 4 mm, 6 mm, 8 mm, 10 mm, 12 mm, 15 mm and 20 mm. Once the cut outs had been created, the stencils were laid onto a kiln shelf and filled with white Gaffer glass powder. The stencil was then removed and the squares were fired in the kiln. It was noted that when removing the thicker Perspex stencils the edges of the squares collapsed (Figure 64).

Figure 63 Backing sheet density tests created from filling different depth Perspex stencils white Gaffer glass powder - each square measures 5 cm x 5 cm

Figure 64 Close-up of backing sheet density tests with collapsed corners - each square measures 5 cm x 5 cm.

One method of overcoming this problem of collapse was to mix the powdered glass with water to form a paste that could be used to infill the cut-outs. This approach ensured that the edges in the thicker cut-outs did not collapse. The following image documents the results of both the dry glass powder and glass paste tests post-firing.

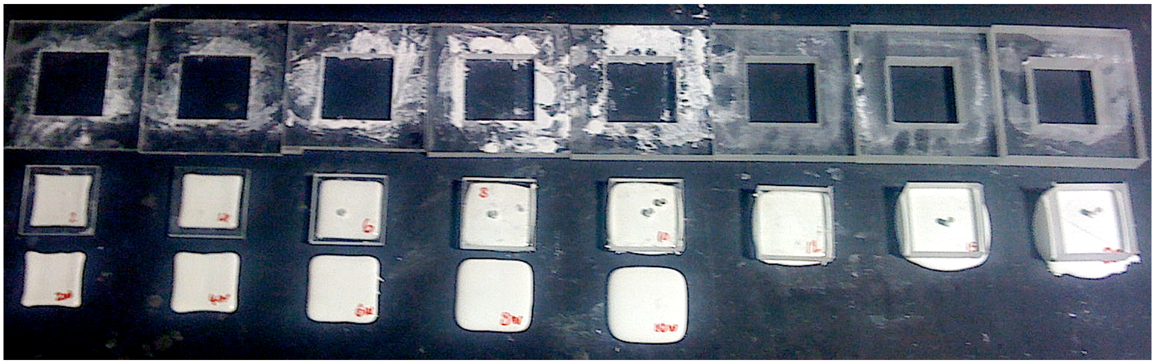


Figure 65 Backing sheet density tests post-firing with original Perspex stencils to demonstrate shrinkage - the dimensions of each square varied post-firing .

Observations of the density tests show that both the powdered and paste formats of glass are successful in creating backing sheets. In comparison to the paste format, the powdered format was easier to use when infilling the stencil, even though collapsing occurred with the thicker stencils. However, collapsing could be eliminated as the tests suggest the optimum thickness of the glass powder is 8 mm. The test created to an 8 mm thickness remained the same size as the original cut out (5 cm squared)

4.5 Process 5 – Utilisation of photopolymer plates to create a patterned roll-up sheet

This process of printmaking is also known as photo-etching, solar-plate printing or flexography and is a method associated with intaglio printmaking processes. Initial interest in this approach developed as a result of the ability to produce a greater range of imagery compared to the hand-carving plaster process (Process 4). Photopolymer plate printing makes it possible to reproduce photographic and computer generated imagery (Petrie, 2006). Photopolymer plate printing also has the advantage of requiring no hand-carving, eliminating some of the work. This is because the textured plate is formed through exposing the polymer surface of the plate to UV light and subsequently washing it away in water (Woods, 1996 p.61). Further interest in this process developed in relation to the integrated glass prints produced by Petrie (2006, p.p.74-78).

Petrie's research in this area focused upon the utilisation of photopolymer plates for the production of shallow plaster moulds. The intaglio details in the plaster moulds were filled with glass frits and fired in a kiln to form glass sheets with raised designs.

The following questions were formulated as a starting point for experimentation.

1. Can a photopolymer plate be exposed with an image to create a relief, patterned plate?

2. Can a plaster mould be taken from the plate, inlaid with Gaffer glass powder then fired in the kiln to create a relief patterned glass sheet?

3. If successful can the Gaffer glass sheet then be pre-heated and rolled onto a blown glass form and embedded in layers of blown glass?

The work of Petrie (2006) had demonstrated the potential of mould forming from photopolymer plates as well as the potential of the moulds for the production of patterned, textured, glass sheets. This, combined with knowledge that it is possible to roll-up glass sheets similar to the ones produced by this process, led to the hypothesis. The hypothesis was that it would be possible to produce a patterned and textured glass sheet taken from the mould of a polymer plate. It would then be possible to roll-up the glass sheet and embed it into the layers of a blown glass form.

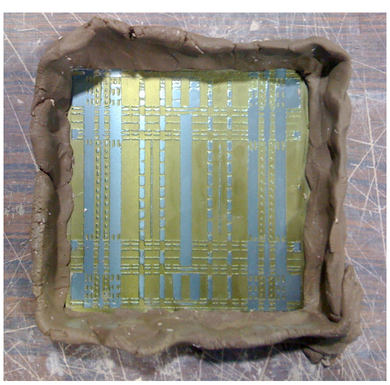


Figure 66 Exposed photopolymer plate with clay dams ready for a plaster mould to be taken – 10 cm x10 cm

Initial testing into this process involved cutting photopolymer plates into nine 10 cm x 10 cm squares. Each square of photopolymer plate was exposed with a different patterned positive for 50 light units on an ultra violet light box (Figure 66). To reveal the relief pattern on the plate the polymer layer was washed away by immersing the plate in warm water and gently rubbing a sponge across the surface. The areas not covered by the black of the positive created the texture and the areas not covered by the positive were washed away (the same principle used in screenprinting).

Once the plate had dried fully and the polymer was no longer sticky to touch a plaster mould was taken. Each individual photopolymer plate was prepared by creating clay dams around the edges of the plate. Wet plaster was poured gently (to eliminate air bubbles) onto the textured surface of the plate. Once the plaster had set the clay dams and plate were removed.

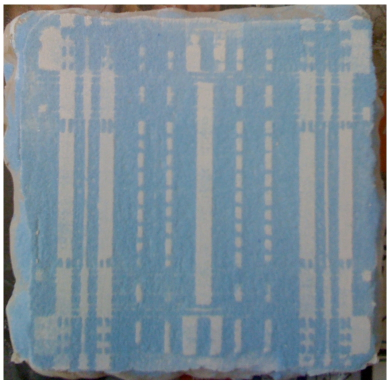


Figure 67 Plaster mould in-filled with blue Gaffer glass powder - 10 cm x 10 cm.

The plaster mould was allowed to dry out before the relief detail in each mould was in-filled with a different colour Gaffer glass powder by scraping a rubber kidney across the surface of the mould (Figure 67). A backing sheet of Gaffer glass powder was spread over the back of each mould to create the backing sheet for the texture. The moulds were placed in a kiln and fired to fuse the glass powder together.

The following kiln cycle was used to fuse the glass powder together:

222°c per hr to 800°c for 30 minutes

222°c per hour to 510°c for 120 minutes

40°c per hour to 405°c no hold time

End

Once the sheet had been formed, the mould was removed and the sheet was cleaned using water and a toothbrush. The following table of images demonstrates the results of nine different patterned glass sheets obtained from using the photopolmer plate process. Figure 68 includes the positive used to expose the plate, the photopolymer plate used to form the plaster mould and the two-dimensional glass sheets kiln-formed from powdered Gaffer glass.

Patterned Positive | **Exposed photopolymer plate** | **Kiln-formred glass powder**

Patterned Positive | **Exposed photopolymer plate** | **Kiln-formred glass powder**

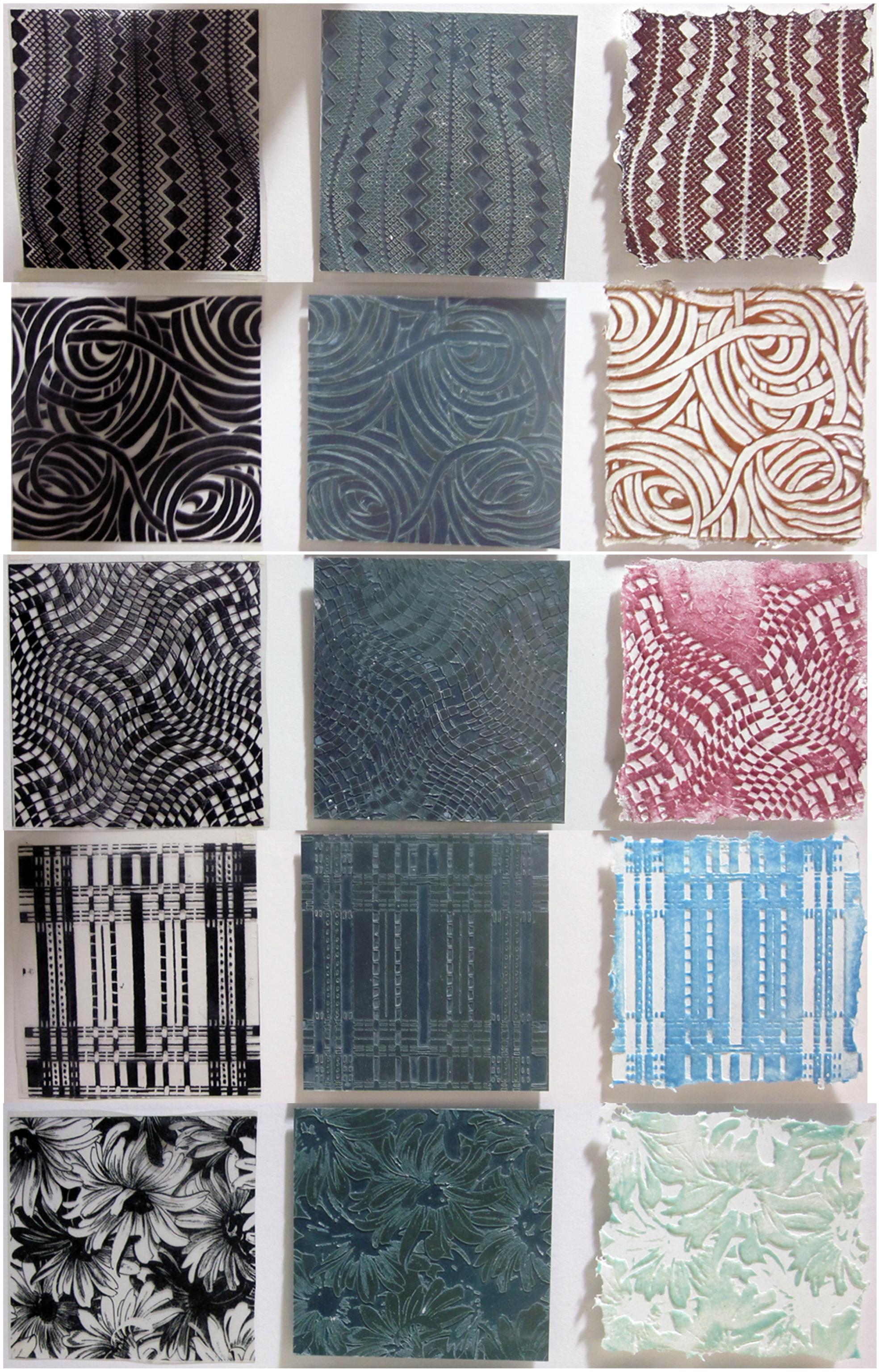


Figure 68 Results of initial photopolymer plate testing -each square measures 10 cm x 10 cm.

Observations of initial photopolymer plate tests demonstrate how it is possible to obtain a kiln-formed, two-dimensional patterned sheet of glass from a plaster mould taken from an exposed photopolymer plate. The variety of patterns used, demonstrate how the process can be effectively adapted for use with a variety of decorative styles. However, some patterns worked better than others. In pattern 7 some of the definition of the geometric squares was lost. This was due to areas of the positive not being dense enough, resulting in these areas being more difficult to wash out as they had not been correctly exposed.

In turn this impacted upon the depth of relief created when taking the plaster mould from the plate and resulted in areas of smudged colour where the relief was not dense enough to fill. When comparing the positive used and sheet of glass created with pattern 10, it was evident that some of the finer line detail in the positive had been lost in the translation of the imagery to glass. However, I feel the glass sheet produced is still an acceptable representation of the original imagery. The most successful glass sheets formed were taken from positives with high contrast imagery for example patterns 1, 4, 6 and 8. Another good indicator of the potential of the process can be seen in pattern 2 where the areas of fine detail have translated well into the glass sheet. None of the patterns used had variations in tone and this is an area for further development.

The process of taking the plaster mould directly from the surface of the plate was not ideal because the moisture in the plaster softened the polymer layer on the plate, causing areas of the pattern to lift off. This meant that the plate could not be reused for successive moulds. Undertaking the process in the same way that the initial tests were conducted resulted in the two-dimensional glass sheet being a negative version of the original artwork. To combat the polymer layer lifting off and to create a two-dimensional glass sheet that was a positive version of the artwork, a former was taken from the photopolymer plate prior to the plaster mould stage. A number of materials were tested to find the most suitable material to create this former. These included gel flex, modeling wax, two-part cold set rubber silicon and alginate.

The temperature of both the gel flex and modeling wax caused the polymer layer to lift away from the backing sheet of metal and destroyed the pattern. The two-part cold set rubber silicon took a long time to cure and in areas it stuck to the plate and could not be removed.

If this material was used in the future, a suitable mould release would need to be sought. The most successful material tested was the alginate. Alginate sets quickly and no heat is given off as it cures. The only disadvantage of using alginate is that will only allow a limited number of moulds to be taken from it before it dries out or is damaged. The rubber silicon would be more suitable if multiple moulds were required.

Another area for further testing was determining the optimum exposure rate for exposing the plates. 50 light units had been used in the initial testing. Further testing to determine the optimum exposure rate was carried out by exposing the same pattern on 5 cm x 5 cm squares of photopolymer plate and exposed to a range of light units. The photopolymer plates were exposed at 10 light units, 20 light units, 30 light units, 40 light units, 50, light units, 60, light units, 90, light units, 120 light units, 150 light units and 180 light units. All of the plates were washed and dried out after exposure. Figure 69 shows the results of the photopolymer plate exposure rate tests.

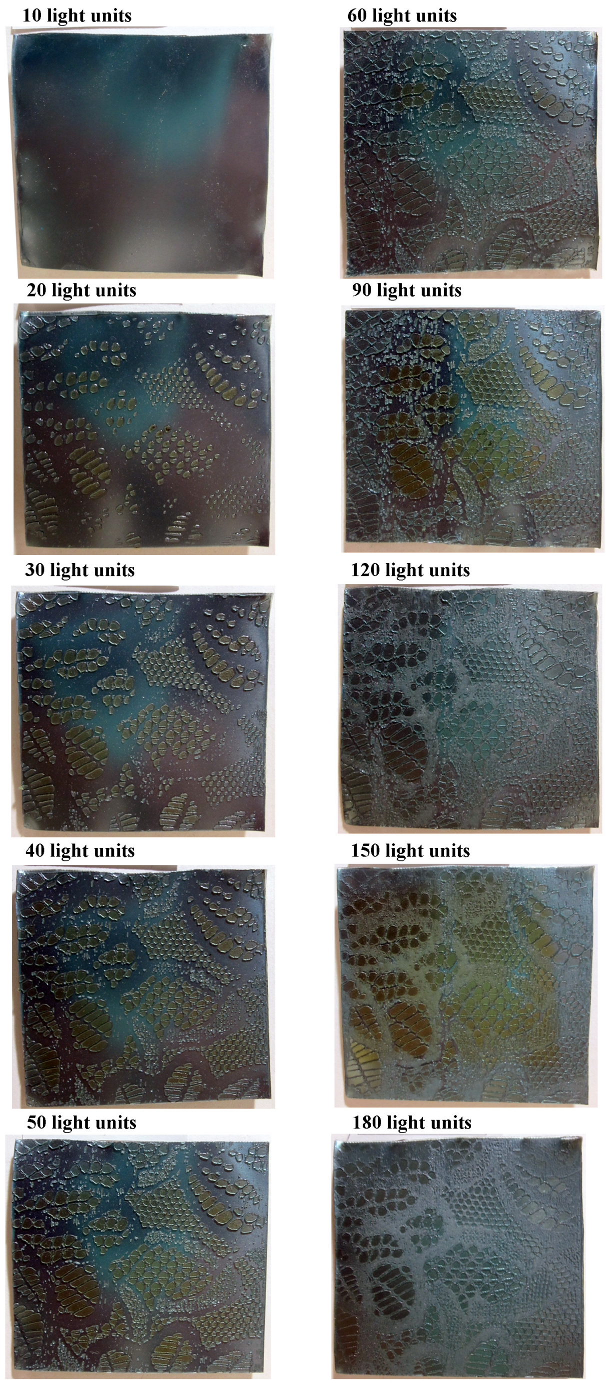


Figure 69 Photopolymer plates exposed at variety of light units - each plate measures 5 cm x 5 cm.

The results of the photopolymer plate exposure rate tests prove that the higher the exposure rate the greater the detail retained when washing the plates out. However, at 120 light units the polymer was difficult to remove when washing out, resulting in a plate that had a very shallow relief. At the other end of the scale the plate exposed to 10 light units was very easy to wash out but none of the detail in the exposed pattern was retained. For the lace pattern used in the tests, the optimum exposure rate lies somewhere between 60-90 light units. Depending on the type of imagery used, the exposure rate could be adjusted accordingly. For example simple high contrast imagery would be better exposed to a rate between 30-50 light units and more detailed imagery would be better exposed between 60-90 light units.

Once the optimum exposure rate had been determined, the next step was to kiln-form a two-dimensional glass sheet from the plate that could be incorporated into a blown glass form. The plate was exposed at 90 light units and a plaster mould was formed from it. The two-dimensional glass sheet was formed using the same process as the initial tests. The two-dimensional glass sheet was taken into the hot shop, pre-heated in the lehr and rolled onto a bubble. An additional layer of glass was gathered to embed the imagery and the hot glass was blown and shaped into a simple cup form (Figure 70)

Figure70 Blown glass form created using photopolymer plate process – 11 cm x 8 cm x 8 cm.

Table 10 – Table showing performance of novel process 5 in relation to the limitations documented in 1.2

Limitation	**Performance of novel process 5**
Stretch and distortion	The stretching and distortion of the image was not improved using this process.
Density	The density of the image was improved using this process as the imagery was taken from the relief surface of the exposed photo-polymer plate.
Detail	The detail of the imagery was not improved using this process but was equal to detail achieved through using a screenprinted transfer.
Compatibility	This process ensured full compatibility of image and glass object by substituting the under-glaze ceramic enamel for Gaffer glass powder. The coefficient value of both the object and image were now the same.
Health and safety	Health and safety was improved using this process, as a solvent based printing medium was not needed.
Available technical information	Limited technical information related to the use of this process for glassmaking. No technical information on combining this process with blown glass.

4.6 Process 6 – Utilisation of laser cutting technology to create a patterned roll-up sheet

Laser cutting technology was explored as an alternative method for the production of relief textured moulds (process 4 and process 5). Initial experimentation into this method involved the use of a section of laser cut felt (Figure 71). The felt stencil was spray mounted on to a sheet of Perspex and a plaster mould taken from it. The plaster mould was filled with black Gaffer glass powder, placed in the kiln and fired to form a patterned glass stencil (Figure 72). The stencil was then taken into the hot shop, rolled up and encased in layers of blown glass.

Figure 71 Laser cut felt

Figure 72 Glass powder kilnformed to create a glass stencil

Figure 73 Blown glass cylinder containing glass stencil formed from a laser cut piece of felt

The initial tests demonstrated the potential for the utilisation of laser cutting technology in the production of a glass stencil. However, the use of felt as the mould former material was not suitable as the plaster used to take the mould stuck to the surface of the felt making removal difficult. Exploration into other materials that could be cut using a laser cutter and used in the production of shallow relief moulds was therefore undertaken. One of the materials deemed suitable was Perspex.

The following questions were formulated for experimentation:

1. Can an image be cut from a Perspex sheet using laser-cutting technology?

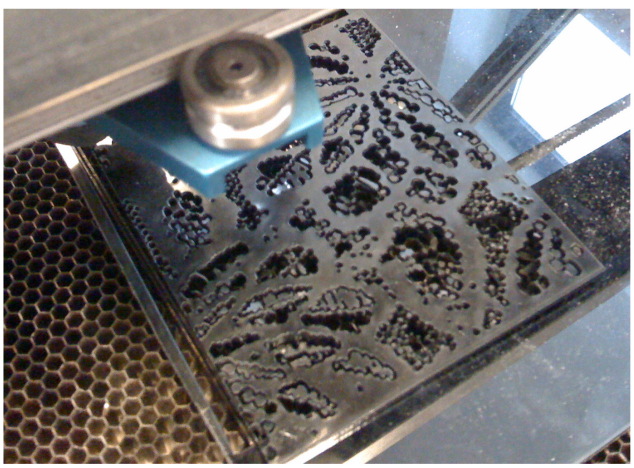
2. Can the cut Perspex sheet then be used to create a silicone mould, which could then be used to create a plaster/molochite mould?

3. Can the plaster/molochite mould be filled with glass powder or glass frit and fired to create a textural sheet of glass or a substantial glass stencil?

4. Can this textural/stencil sheet be manipulated to create a three-dimensional textured form?

Technical advice from staff at the university of Sunderland had already confirmed that Perspex would be a suitable material for use with the laser cutter. This knowledge, combined with the fact that initial testing in this area had been successful in obtaining a glass stencil which had been rolled-up and embedded into the layers of a blown glass form led to the formulation of the hypothesis. The hypothesis was that it would be possible to create either a patterned glass stencil or a patterned, textured sheet of glass from a laser cut piece of Perspex. It would also be possible to roll-up and embed the glass stencil/sheet into the layers of a blown glass form.

A 10 cm x 10 cm square of lace imagery was transformed into a vector image using Adobe Photoshop and Illustrator software. The vector image was then programmed for laser cutting. Perspex with a depth of 4 mm was cut with the lace pattern (Figure 74).



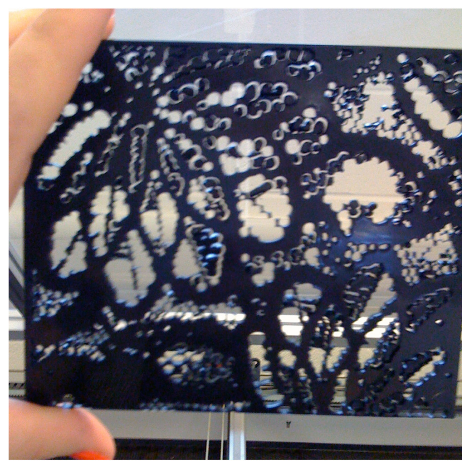


Figure 74 Laser cut Perpex sheet -10cm x 10cm

Observations of the Perspex following laser cutting suggested that this particular style of imagery may be more suited to a sheet of glass containing the imagery rather than a glass stencil. This decision was made as the glass normally shrinks in the kiln-forming process, resulting in a loss in the finer details of the lace.

Figure 75 Rubber silicon former taken from laser cut Perspex sheet – 10 cm x 10 cm

Once the lace pattern had been cut into the Perspex, a mould was taken from its surface using two-part, cold set, rubber silicon (Figure 75). The mould became the former for a subsequent plaster mould. The relief areas in the plaster mould were then in-filled with Gaffer glass powder and a backing layer of white Gaffer glass powder was spread over the back of the mould to form a backing layer for the pattern. The mould was placed in the kiln and fired to fuse the glass powder together to form a two-dimensional glass sheet. The following kiln cycle was used to fuse the glass powder together:

222°c per hr to 800°c for 30 minutes
222°c per hour to 510°c for 120 minutes
40°c per hour to 405°c no hold time
End

Once the sheet had been formed, the mould was removed and the sheet was cleaned using water and a toothbrush (Figure 76).

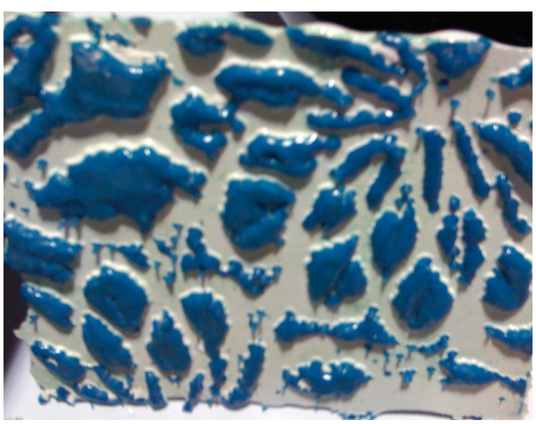


Figure 76 Glass sheet formed from laser cut Perspex sheet – 10 cm x 10 cm

Table 11 – Table showing performance of novel process 6 in relation to the limitations documented in 1.2

Limitation	Performance of novel process 6
Stretch and distortion	The stretching and distortion of the image was not improved using this process.
Density	The density of the image was improved using this process as the imagery was formed from the relief surface of the laser cut felt.
Detail	The detail of the imagery became more limited when using this process as the production of a stencil requires the imagery to have closed parts so that it forms a whole structure.
Compatibility	This process ensured full compatibility of image and glass object by substituting the under-glaze ceramic enamel for Gaffer glass powder. The coefficient value of both the object and image were now the same.
Health and safety	Health and safety was improved using this process, as a solvent based printing medium was not needed.
Available technical information	Limited technical information related to the use of this process for glassmaking. No technical information on combining this process with blown glass.

In conclusion it was possible to form a textured glass sheet from a laser cut piece of Perspex. With this process it was not deemed suitable to integrate the glass sheet into blown glass without further refinement in relation to the types of imagery that could be produced. It was also anticipated that water-jet cutting would offer a more suitable process for the creation of a textured sheet of glass (See 4.7).

4.7 Process 7 - Utilisation of water-jet cutting technology to create a patterned roll-up sheet.

Water-jet cutting technology was explored as an alternative process for the creation of a patterned glass stencil or patterned sheet of glass. The use of the water-jet cutter would bypass the mould making elements of the previous process by directly cutting the pattern from the sheet of glass rather than the Perspex. Water-jet technology enables the cutting of intricate shapes, accurate lines and milling within sheets of glass. Research into the creative use of water-jet cutting for glass has been carried out by Vanessa Cutler (2006). Her research focused on extending the vocabulary of the glass artist through the introduction of the industrial water-jet cutting process. Despite Cutler's research focusing on architectural glass, she did acknowledge the utilisation of water-jet cut glass for the creation of blown glass artworks. This was carried out through collaboration with blown glass artists such as James Maskrey and Scott Chaseling.

The research undertaken with these artists included the cutting of glass forms after they had been blown as well as the development of inter-locking glass shapes that could be fitted together then fused into complete sheets of glass. These sheets of glass were then incorporated into the blown glass forms as an inclusion or combined with the roll-up process to create the form. One element not addressed in Cutler's research was the use of the water-jet cut glass stencils for the production of textural blown glass forms.

The following questions were formulated for experimentation:

1. Can imagery be programmed and water-jet cut from Bullseye sheet glass to either form a glass stencil or a patterned sheet that has been fused back together?

2. Can this stencil/sheet then be rolled-up and either manipulated or encased and blown to create three dimensional patterned/textured forms?

With the knowledge gained from Cutler's research, the hypothesis formulated in relation to this process was that it would be possible to form a patterned, textured water-jet cut sheet of glass that could be rolled-up to form a patterned, textured blown glass form.

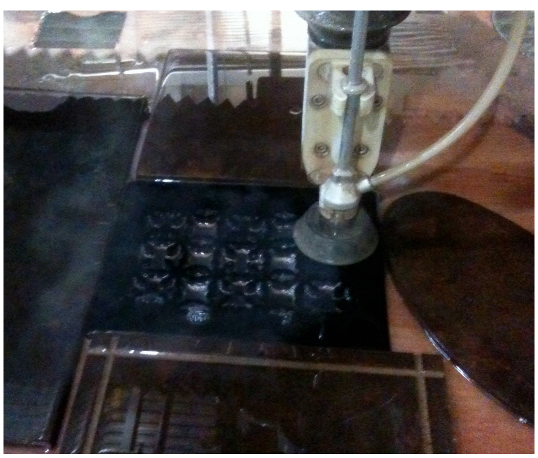
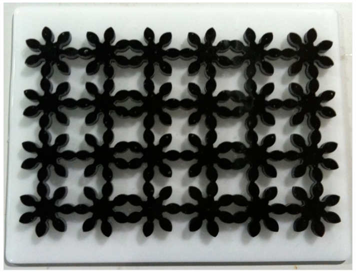


Figure 77 6 mm Bullseye glass sheet being water-jet cut - 24 cm x 20 cm

The first step was to use Autocad drawing software to create an accurate drawing of the pattern to be cut from the sheet of Bullseye glass. This drawing was translated to the specific software (Lantek) used to program the water-jet cutter. Before the sheet of glass could be cut it was fused to another sheet of glass to make the overall thickness of the glass stencil 6 mm. The 6 mm sheet of Bullseye glass was set up on the cutting bed by weighting the glass down so it would not move or float away during cutting. A piercing cycle was needed as a starting point for cutting the external and internal shapes in the pattern (Figure 77). Once the glass had been pierced, a cutting cycle was run to cut the outlines of the glass stencil.

Figure 78 6 mm water-jet cut Bullseye glass stencil – 24 cm x 20 cm

After cutting the glass stencil it was fused to a backing sheet of white Bullseye glass that had also been pre-fused to another sheet to make it 6 mm in diameter. The textured glass sheet was taken into the hot shop and rolled-up and blown into a three-dimensional glass form (Figure 79).



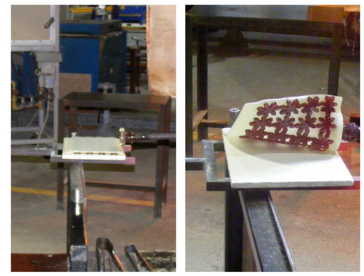
In preparation for pick up the sheet was placed face down on a batt washed kiln shelf. The shelf was placed on a kiln prop inside the lehr. The temperature of the lehr was gradually brought up 50 degrees per hour until it reached 560 degrees celsius.

A collar was prepared on a blowing iron by taking a gather of glass from the furnace, blowing a bubble in it, then shaping the glass into a disc shape using the jacks. The diameter of the disc was calibrated in size to match up with the length of the sheets edge that was going to be rolled up.

Whilst the collar was being prepared the pre-heated sheet of printed glass was picked up from the lehr using a pastorelli.

The pastorelli was carried straigh to the glory hole where the glass sheet was heated. Due to the thickness of the printed sheet multiple re heats in the glory hole were required.

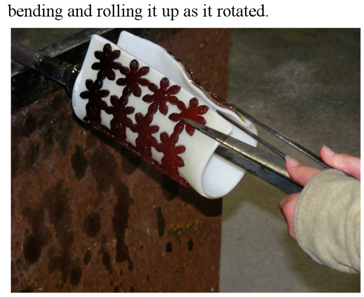
To check how much heat and how evenly distributed the heat in the sheet was it was brought to the bench and the corners were lifted using tweezers. If the corners were soft and bendy the panel was ready for roll up. The kiln shelf was also turned around on the pastorelli to ensure even heat.



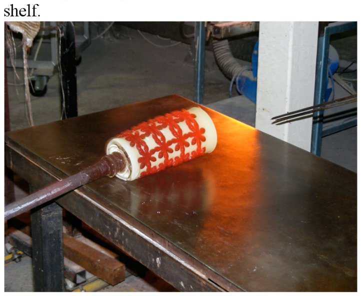
Whilst the sheet was being heated the collar was also re heated till it was just glowing red. The pastorelli was placed on the bench and the collar was touched down to stick it onto the sheet. The collar was then rolled along the edge of the sheet, bending and rolling it up as it rotated.

Once the pastorelli had been removed and the sheet had been flashed in the glory hole it was brought back to the bench and dusted using a newspaper pad. This was done to remove any of the dust picked up from the batt washed kiln shelf.

The edges of the sheet then had to be joined. Inbetween reheats the edges were sewn together.



The edges furthest away from the collar were joined first working back towrads the collar. The tweezers were used to grip the edges and touch them together. Finally the back edges were pressed against the collar. The sheet had been transformed into a cylindrical form.



To ensure the seam had fully sealed, further reheating and marvering was undertaken. Marvering also ensured everything was straight and the seam was flat.

The cylinder was sealed by creating a cut line with the jacks approximately 2cm from the edge.The jacks were squeezed tight. The end piece was cooled down and knocked off by filing around it then gently tapping it with a file.

The sealed bubble was blown up at the bench and a cut line was inserted with the jacks. Once happy with the form the piece was given a final reheat to even the temperature, the jack line was filed around and the piece was cooled down in lehr.

Figure 80 Blown glass form created from patterned, textured water-jet cut glass sheet - 20 cm x 12 cm x 12 cm

Table 12 – Table showing performance of novel process 7 in relation to the limitations documented in 1.2.

Limitation	Performance of novel process 7
Stretch and distortion	The stretching and distortion of the image was not improved using this process.
Density	The density of the image was improved using this process as the imagery had a depth of 6mm.
Detail	The detail of the imagery became more limited when using this process as the use of water-jet cutter requires imagery with closed contours. The thinness of line created by the water-jet cutter is limited as the glass would become fragile and break during cutting.
Compatibility	This process ensured full compatibility of image and glass object by substituting the under-glaze ceramic enamel for Gaffer glass powder. The coefficient value of both the object and image were now the same.
Health and safety	Health and safety was improved using this process, as a solvent based printing medium was not needed.
Available technical information	Limited technical information related to the use of this process for glassmaking. No technical information on combining this process with blown glass.

In conclusion although process 7 facilitated the production of a patterned, textured blown glass form, the visual qualities of the test were not considered acceptable for use in professional practice. The main advantage was that the density of the imagery was improved and, as a result, texture was created.

There is scope for refinement and further exploration into the use of the water-jet cutter for the production of decorative blown glass forms.

4.8 Summary of chapter 4

In this chapter seven novel print inspired processes were explored and developed for integration into blown glass as a means of decoration. Although all of the seven processes offered alternative ways of producing decoration, it was concluded that the most successful processes for integration with blown glass forms were process 3 and process 5. Process 3 involved screenprinting glass powder onto sheet glass that was subsequently rolled-up to create a blown glass form. This process successfully addressed the limitations outlined in 1.2. Process 5 involved kiln-forming a glass sheet from a mould that was taken from a photopolymer plate. The glass sheet was subsequently rolled-up to create a blown glass form. Again process 5 successfully addressed the limitations outlined in 1.2. Both of these processes produced imagery that could be embedded into the layers of a blown glass form.

It was also concluded from the development of the novel print inspired processes that, even though some of the tests were not entirely suitable for integration with blown glass forms, they produced visual qualities particularly suited to kiln-forming, such as the production of texture.

Artworks will be created to confirm the viability of the novel printed inspired processes from the perspective of a studio artist (Chapter 5).

5. Development of artworks to substantiate the research

Chapter 5 relates to aim and objective 3 of the research to develop the novel print inspired glass processes to create artworks for my own studio practice and as models for other practitioners. It describes how the artworks were created and discusses the potential advantages and disadvantages of the creative print inspired processes used to produce the artworks.

5.1 Rationale for the production of artwork

In this practice based research study it was considered necessary to include creative artworks to demonstrate the practical aspects of the research and illustrate the visual qualities that can be that can be achieved through the utilisation of the creative print inspired glass processes outlined in chapter 4. This could offer practitioners in the field of hot glass and print alternative printmaking processes that overcome the limitations documented in 1.2. As a practicing glass artist, it was important that these creative artworks were part of my present and future studio practice. The production of artworks would demonstrate new routes in terms of the visual qualities that can be achieved by combining glassmaking and printmaking processes in the production of decorative blown glass objects. Sections 5.8, 5.9 and 5.10 document artworks where the creative print inspired processes documented in Chapter 4 are not used. However, they still combine glassmaking and printmaking processes.

5.2 'Wallflowers'

'Wallflowers' (2009) (Figure 81) were produced using the photopolymer plate process (See 4.5). The repeats were created to test the viability of scaling up the initial 10 cm square test pieces to produce 30 cm square artwork. The artwork consisted of ten wall mounted glass repeats, using two different patterns in five different colours and both patterns were based on lace fabric. The repeats were produced mid point in my research and at this stage the emphasis was on perfecting the creative print inspired processes on a two-dimensional level prior to application to a three-dimensional blown glass form. The repeats were part of a collection of work for display at Brighton Art Fair in October 2009.

Figure 81 -'Wallflowers' 2009 –Kiln formed glass repeat moulded from a photopolymer plate - 30 cm x 30 cm

Figure 82 'Wallflowers' 2009 – Kiln formed glass repeat moulded from a photopolymer plate - 30 cm x 30 cm

The repeats were created by exposing the chosen image onto a photopolymer plate using an ultraviolet light-box - 80 light units (See 4.5). The image was revealed when the plate was immersed in water and the surface gently rubbed with a sponge to remove the polymer and expose the metal plate. The metal plate was removed from the water and allowed to dry overnight. At this stage the plate would have been capable of producing an intaglio print. In order to form a glass sheet, it was necessary to take a Silicon former from the plate. As detailed in section 4.5, a 10 cm former was produced by using slow set alginate. However, problems were encountered when attempting to mix the larger quantity of slow set alginate required for a 30 cm square mould. The texture of the alginate became 'dough like' and 'lumpy' rather than the required pourable consistency. This was due to the increased time it took to physically mix the powder and water together. To overcome this problem an alternative material to create the former was sourced. The product selected was a two-part cold setting rubber silicon (RTV 4420 - Bentley chemicals). A mould release was also used to spray onto the surface of the mould to ensure that the silicon did not stick to the plate.

Once the former had been produced, a plaster/molochite mould was obtained. The mixing ratio was 1 lb of plaster to 1.5 lbs of molochite to 1 pint of water. The moulds were placed in a drying cabinet and allowed to dry thoroughly. It was then possible to in-fill the plaster mould with coloured glass powder. If the mould had not been allowed to dry thoroughly, the glass powder would have become damp and it would have stuck to the surface of the plaster mould. As a result it would have been difficult to remove the excess powder before applying the backing layer of powder. The coloured glass powder was applied by placing a spoonful of powder onto the middle of the mould and then scraping a rubber kidney across the surface to remove the coloured powder from the raised areas of the mould. A thick layer (approximately 8 mm) of white glass powder was sieved over the surface of the mould to create the backing sheet for the pattern. The mould was placed in the kiln and fired.

The firing cycle (kiln 16) used was:

30ºc per hour to 90ºc for 120 minutes

50ºc per hour to 600ºc for 0 minutes

100ºc per hour to 800ºc for 30 minutes

100ºc per hour to 510ºc for 120 minutes

10ºc per hour to 405ºc for 0 minutes

20ºc per hour to 100ºc for 0 minutes

End

Once the cycle had ended, the repeats were removed from the kiln, demoulded and cleaned with a toothbrush.

I felt that the glass repeats produced were of a professional standard and suitable for sale at the Brighton Art Fair. Using the photopolymer plate process created artwork that had a 'paper-like' appearance, a quality synonymous with printmaking but unusual in glassmaking. When viewing the repeats from a distance, the pattern was the predominant feature but, when viewed close up, the subtlety of the texture became apparent. When using this process the detail in the two lace patterns was not compromised and the use of two contrasting colours effectively highlighted the pattern in the lace. Once fired, the coloured glass was shiny and contrasted with the matt white backing sheet, adding to the visual qualities of the photopolymer plate process.

Some of the panels had imperfections once fired. These appeared as either a vein or a split and were caused by the mould cracking during the initial part of the kiln cycle. One explanation for the mould cracking was that it may not have dried out sufficiently. A further problem occurred during the in-fill process when using peach Gaffer glass powder, which in powder format was almost white. This meant it was difficult to remove excess powder from the raised areas of the mould as the mould and the powder were a similar colour, resulting in a repeat where the colour tone of the image varied.

Using the photopolymer plate process in a studio setting is a viable option for glassmakers. It is a cost effective process possible of producing artworks with small quantities of material and using the standard equipment found in a kiln glass studio. Even though the rubber Silicon used to take the initial mould from the photopolymer plate appears expensive, it has the potential to produce multiple reproductions before being renewed. This process can also be used to embed imagery into the layers of blown glass forms.

Figure 83 'Roses are Red' 2010 Kiln formed glass repeat moulded from a photopolymer plate subsequently rolled-up and embedded into layer of a blown glass cylinder - approximately 35 cm x 11 cm x 11 cm.

Figure 83 shows a blown glass cylinder that has been created by rolling-up a 'wallflower panel' made from Bullseye Glass and embedding it into layers of blown glass. The relationship between the printed image and the form created is the main focus of this decorative artwork.

5.3 'Every picture tells a story'

Figure 84 'Every picture tells a story' 2010 'Kiln formed glass moulded from a photopolymer plate - each glass image measures approximately 10 cm x 6 cm.

‘Every picture tells a story’ (2010) (Figure 84) is a series of 31 kiln-formed glass images (approx 10 cm x 6 cm) of my ‘granny’ as a young woman. The glass images were made using the photopolymer plate process. Even though this process had been used successfully to create ‘Wallflowers’ (2009), it was felt that introducing a different type of imagery such as a photographic image would challenge the process further.

Even though the Wallflower repeats demonstrated that it was possible to produce fine detail, they did not demonstrate if it was possible to produce tonal quality. Therefore, the challenge was to reproduce the tonal qualities found in photographic imagery using the photopolymer plate process developed for glass (see 4.5).

Figure 85 ‘Every picture tells a story’ 2010 Installation setup. Kiln formed glass moulded from a photopolymer plate - each photo measures approximately 10 cm x 6 cm

The narrative behind this artwork is an important element that seeks to explore and preserve cultural roots. The series is accompanied by an audio-loop that recounts the background of each picture and allows the audience to appreciate the stories behind the pictures. It also reflects the culture my grandma grew up in and preserves experiences, family values and memories for future generations. This body of artwork was selected for the British Glass Biennale 2010 and was exhibited as an installation piece where the glass photographs were displayed on a replica set up of my grandma’s living room (Figure 85).

To create this artwork, the original black and white photographs were scanned into a computer and digitally altered using Photoshop software. Altering the images involved experimenting with the threshold and half tone appearance of the photographs so that tone could be represented.

The glass photographs were subsequently created using the same process as used in ‘Wallflowers’ (2009) but, as the photographs were smaller in size, slow set alginate could be used to take the initial mould from the photopolymer plate rather than rubber silicon. This was more cost effective. Once the plaster/molochite moulds had been taken from the alginate and fully dried out, the intaglio detail was in-filled with black Gaffer glass powder and a backing layer (approximately 8 mm in diameter) of white Gaffer glass powder was sieved on top to create a backing sheet. It was apparent when in-filling the mould with the black Gaffer glass powder, how much detail would be seen post-firing. The moulds were placed in the kiln and fired.

The firing cycle (kiln 8) used was:
30ºc per hour to 90ºc for 90 minutes
50ºc per hour to 600ºc for 0 minutes
100ºc per hour to 780ºc for 30 minutes
100ºc per hour to 510ºc for 120 minutes
40ºc per hour to 405ºc for 0 minutes
End
Once the cycle had ended, the glass photographs were removed from the kiln, de-moulded and cleaned with a toothbrush.

I feel the kiln-formed glass images created were of a professional standard. Similar to the Wallflower repeats, the photographs had a paper-like quality synonymous with the original photographs (Figure 86) The kiln-formed images were considered to be a fair representation of the original photographs with good tonal quality and detail. Although the glass images were not an exact replica of the original photographs, I felt they encompassed the vintage sensibility behind the artwork.

Original photograph **Plaster/molochite mould infilled with black glass powder** **Kiln formed glass photograph**

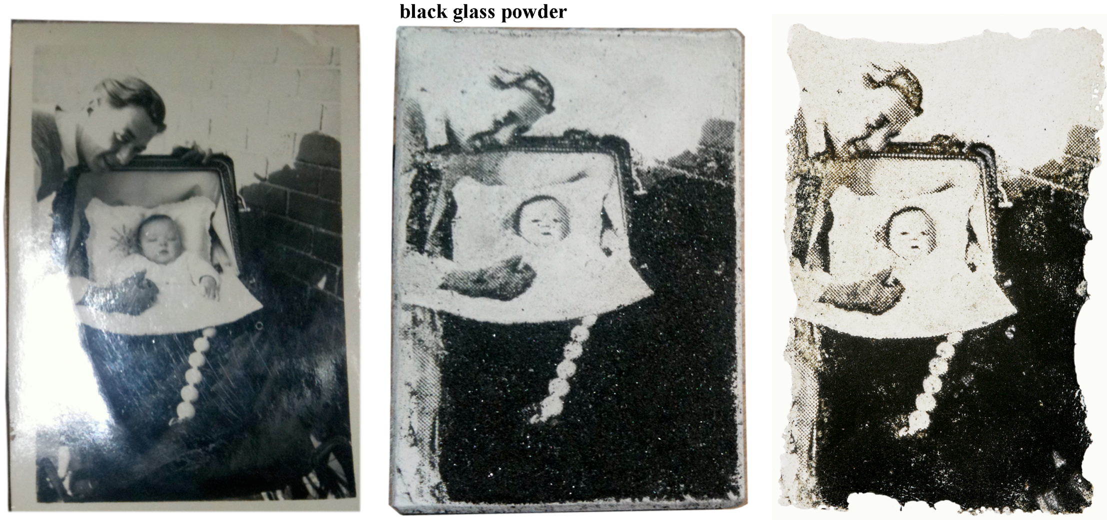


Figure 86 - 'Every picture tells a story' (2010). Comparison between original photograph, plaster/molochite mould and kilnformed glass image.

Allowance had to be made for shrinkage of the glass image during the firing cycle. The glass images shrunk by approximately 5 mm at each edge, resulting in 5 mm of the image from each edge being lost. Depending on imagery used, shrinkage could spoil the overall result. Shrinkage was caused by an insufficient depth or uneven layer of white powder used to form the backing sheet of the glass photograph (see 4.4).

When in-filling the mould with the black glass powder, care had to be taken if there were large dense areas as it was difficult to get the powder to stay in the relief areas of the mould. This was also the case where there were areas of fine detail such as in facial features where the relief areas were shallow.

5.4 'Perpetual Pattern'

'Perpetual Pattern' (2010) was created for my Ph.D. exhibition at the National Glass Centre Sunderland. The pieces were made using the process of screenprinting and fusing multiple layers of glass powder onto layers of sheet glass (See 4.3). The sheets were subsequently rolled-up, gathered over and blown into cylindrical forms.

Figure 87 'Perpetual Pattern' 2010 Screenprinted and kiln formed glass powder on sheet glass subsequently rolled up to form cylindrical vessels - approximately 40 cm x 9 cm x 9 cm.

Although originally five vessels were designed and made, only three vessels were chosen for display in the exhibition (Figure 87). To create these vessels, five patterns were designed using Photoshop software. The patterns were separated into either a three or four layer pattern depending upon how many colours were needed. A screen for each coloured layer was prepared and screenprinted with glass powder onto clear 3 mm sheet glass. Bullseye glass powder was chosen for use with this process as it can be purchased in both sheet, powder and furnace batch format. The distance between the sheet glass and the surface of the screen was 6 mm. 18 layers of each coloured powder were pushed through the screen during printing and subsequently fired in the kiln to form the imagery. The firing cycle (kiln 19) used was:

222ºc per hour to 780ºc for 10 minutes

222ºc per hour to 483ºc for 60 minutes

End

Once each coloured layer making up the pattern had been fired, the layers were assembled and fused together in the kiln to form the patterned glass sheet for roll-up.

The firing cycle (kiln 19) used was:

222ºc per hour to 670ºc for 60 minutes

333ºc per hour to 804ºc for 10 minutes

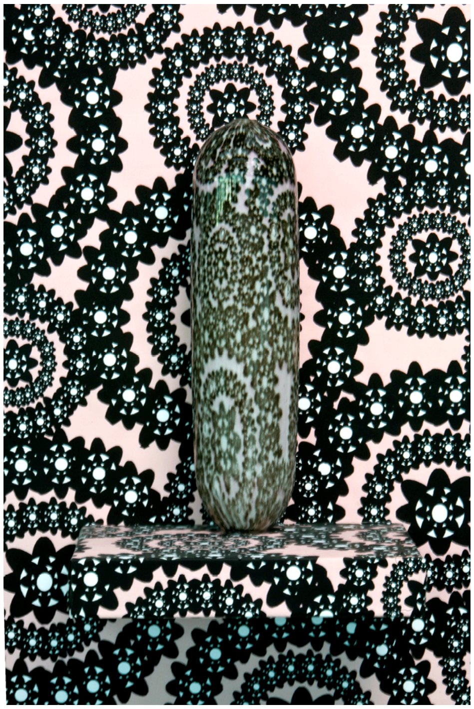
333ºc per hour to 483ºc for 90 minutes

End

The use of Photoshop software as a design tool for the screenprinted patterns was successful in providing accurate visualisation of how the patterns would appear following translation into glass (Figure 88).

Figure 88 'Perpetual Pattern' 2010 Comparison between original pattern designed with Photoshop software and two-dimensional glass sheets screenprinted with glass powder – 24 cm x 20 cm.

Once the patterned sheet for roll-up had been fused, the next step was to form three-dimensional forms from the two-dimensional sheets. To achieve this the five panels were taken into the hot shop, rolled-up, embedded into a layer of glass and blown into five cylindrical shaped vessels (See 4.3).



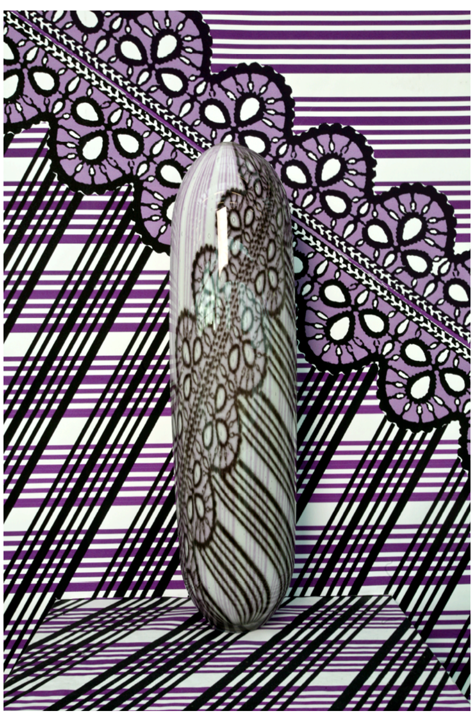


Figure 89 'Perpetual Pattern' 2010) Close up of screenprinted and kiln formed glass powder on sheet glass subsequently rolled-up up to form cylindrical vessels - approximately 40 cm x 9 cm x 9 cm.

Figure 89 are of the two blown glass forms that were not exhibited in my Ph.D. exhibition at the National Glass Centre, Sunderland (2010)

Figure 90 'Perpetual Pattern' 2010 Screenprinted and kiln-formed glass powder on sheet glass subsequently rolled-up to form vessels.

The process of screenprinting powdered glass imagery onto sheet glass and subsequently embedding it into layers of blown glass, created patterned objects that exploited the use of sheet glass as a layering material. As the overall pattern was built up in layers, it added a feeling of depth to the artwork. Using this method of creating decoration, combined with the roll-up process, allowed me to create all-over patterned objects that retained acceptable proportions during the blowing process.

5.5 'Peep show'

Figure 91 'Peep show' (2010) Screenprinted and kiln formed glass powder on sheet glass subsequently rolled-up blown manipulated to form tear drop shape shaped vessel

‘Peep show’ (2010) is a series of three vessel forms featuring ladies in provocative poses (Figure 91). The viewer has to peer through the keyhole on the front of the vessel in order to see the lady on the inside of the vessel. ‘Peep show’ (2010) was made using the process of screenprinting and fusing multiple layers of Bullseye glass powder onto layers of sheet glass (See 4.3). The sheets were subsequently rolled-up, gathered over and blown (See 4.3). The rationale for this artwork was to demonstrate how the process could be used to display an instantly recognisable image such as the female form.

Figuren 92 ‘Peep show’ 2010 Two-dimensional sheet glass screenprinted and kiln-formed with glass powder prior to roll-up – 24 cm x 20 cm.

Due to the rhythmical nature of the imagery in ‘Perpetual Pattern’, it was felt that if distortion occurred during the blowing process, it would not be detrimental to the artwork. This was not the case with ‘Peep Show’ where distortion would have spoilt the imagery. When designing this artwork, the placement of the figure and keyhole was an integral part of the design. To achieve the required form, the neck of the blown vessel had to be pulled out. This meant that the imagery had to be placed in the lower two thirds of the sheet to combat the distortion that would occur in the upper third during the blowing and forming stage. This worked well and resulted in minimal distortion of both the figure and keyhole.

One disappointing feature in the 'Peep show' vessels was the clarity of the viewing keyhole. The keyholes have air bubbles trapped in the layers of clear glass. These bubbles occurred when the sheets of clear glass were initially fused together prior to printing. The bubbles were caused by the textured surface of the sheet glass not becoming flat enough before it was sandwiched together. A longer bubble soak and higher fusing temperature could be added to the firing cycle to minimise bubbles. The other issue is that the keyhole is not as crystal clear as anticipated and some frosting of the clear glass occurred. This may have been attributed to devitrification which occurred during the multiple kiln firings that the glass was subject to prior to roll-up.

5.6 'A little bit of lace'

Figure 93 'A little bit of lace' 2010 Screenprinted and kilnformed glass powder – 30 cm x 30 cm.

‘A little bit of lace’ (2010) (Figure 93) was produced using the process of direct screenprinting Gaffer glass powder onto a kiln shelf then fusing it together in a kiln (See 4.2). This artwork was produced to demonstrate the potential of this process as a kiln-forming process rather than a process of decorating blown glass objects. To create this artwork a number of issues were addressed. These included – producing a larger object, creating an object with edges that did not distort during the firing cycle and turning the glass print into three-dimensional artwork. An indication that these challenges were successfully overcome was that the final artwork was selected as an exhibit at the British Glass Biennale 2010.

To create this artwork Photoshop software was used to turn a small section from a lace panel into a larger repeat pattern. The pattern was then exposed onto a 34t mesh silk screen. To create the scalloped edges of the doily, two scalloped shapes (one square and one round), were drawn in illustrator and cut on a vinyl cutter. The vinyl was applied to the underside of the screen prior to printing. The screen was set up and clamped onto a batt washed kiln shelf with a gap of 6 mm between the kiln shelf and the surface of the screen. Black Gaffer glass powder was applied to the bottom of the screen and pushed through the surface 16 times to create the powder print. The shelf was carefully transferred to the kiln for firing.

The firing cycle (kiln 19) used was:

400ºc per hour to 720ºc for 10 minutes

400ºc per hour to 510ºc for 60 minutes

End

The flat printed object was placed onto a slumping former and fired to form a curved object.

The firing cycle (kiln 19) used was:

200ºc per hour to 650ºc for 10 minutes

200ºc per hour to 510ºc for 60 minutes

End

Both black and white glass doilies were created using this method.

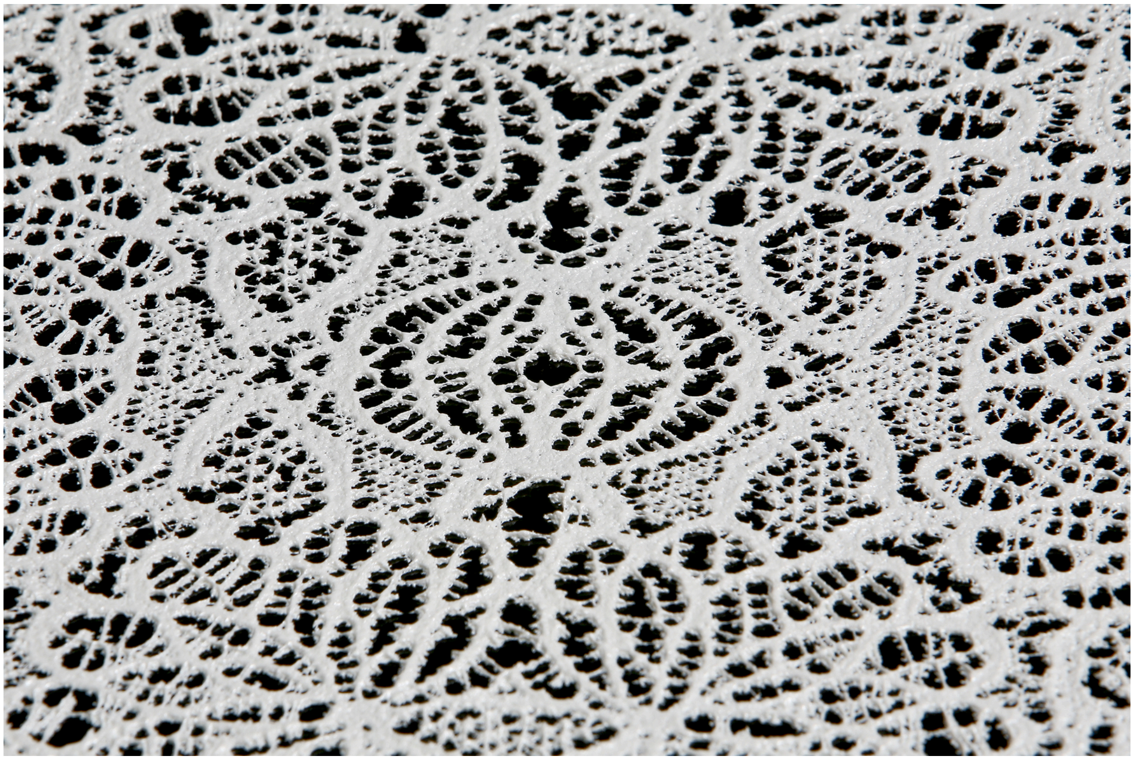


Figure 94 'A little bit of lace' 2010 Close up of detail from a white doiley - screenprinted and kiln-formed glass powder.

The process of screenprinting glass powder directly into the kiln and subsequently fusing it together in the kiln has the ability to produce an object from glass that is delicate and intricate in appearance, qualities found in fabrics such as lace (Figure 94). The artwork engages the viewer as it appears to be made from fabric and it is only on closer inspection that you realise it is actually glass and not fabric. The shadows projected from the glass doily onto the display surfaces are an interesting visual effect achieved from the slumping process A limitation of this method is that only certain types of imagery can be produced. For example imagery where elements do not form closed contours would not work as this method relies on joined up shapes to form the structured piece of glass. The fragility of the artwork is another limitation that will need to be overcome. Because of the tactile nature of the piece, the work currently has to be displayed in a display unit as constant handling would cause damage.

5.7 'A lot of lace'

'A lot of lace' (2010) (Figure 95) was produced for my final Ph.D. exhibition at the National Glass Centre Sunderland. Two large-scale panels (200 cm x 125 cm) were created, one made up of black doilies and one made up of white doilies. Each panel was made up of approximately one hundred doilies in three different sizes. The doily panels were presented with a vinyl cut frame around them to highlight that their purpose that was to decorate a large wall space.

Figure 95 'A lot of lace' 2010 Installation of screenprinted and kiln formed glass powder doilies with vinyl cut frame - each panel measures approximately 200 cm x 125 cm.

The doilies were made using the same process as ‘A little bit of lace’ (2010) and can be viewed as a development of the process, focusing on layering the printed glass objects to make a strong visual statement. By overlapping flat and curved doilies it was possible to create a visual statement rich in texture, tone and depth (Figure 96 and Figure 97)

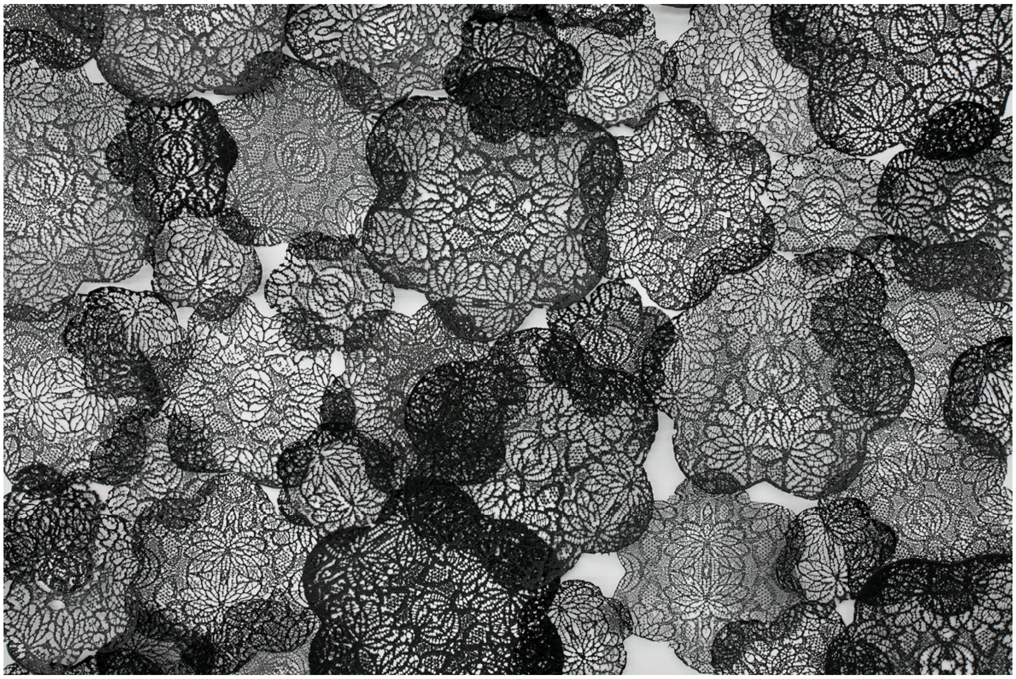


Figure 96 ‘A lot of lace’ 2010 Close up of detail - installation of screenprinted and kiln-formed glass powder doilies with vinyl cut frame - each panel measures approximately 200 cm x 125 cm.

Figure 97 ‘A lot of lace’ 2010 Close up of detail - installation of screenprinted and kiln-formed glass powder doilies with vinyl cut frame - each panel measures approximately 200 cm x 125 cm

5.8 'Opposites attract'

Figure 98 Opposites attract 2008 Hand-blown, multi-layered ovoid forms with embedded screenprinted transfers - approximately 32 cm x 16 cm

'Opposites attract' (2008) (Figure 98) consists of two hand-blown multi-layered ovoid forms incorporating a screenprinted pattern and finished with cut and polished edges. These were the first artworks produced once the limitations of the research had been identified (see 1.2) and they were created for an exhibition. It was also the first work in which I incorporated printed imagery on to the inside of a form.

The black form, where the screenprinted pattern appears on the inside of the piece, was created using a cup casing process. This is a process I had not used previously in combination with screenprinted transfers. The process required the creation of a cased cup that was white on the inside and black on the outside. The cup was kept hot in a top-loading kiln whilst an embryo containing the printed transfer was picked up and encased in a layer of clear glass. Once the embryo reached the required temperature, the top-loading kiln was opened and the printed embryo was inserted into the cup and gently blown so that the surface of the embryo stuck to the inside of the cup. This created a white backdrop for the printed pattern.

The piece was worked on the marver to shape the sides and push out any trapped air. Once shaped, the piece was gathered over and blown into the final ovoid form. It should be noted that once the embryo was inserted into the cup, the pattern was no longer visible as it was on the inside of the form. Prior to attempting to apply pattern to the inside of a blown glass ovoid form, the form was created many times as a means of understanding the characteristics of the form e.g. where the form needed to be stretched, where the form needed to be pinched in etc. This helped inform my knowledge of how the pattern would eventually appear on the inside of the piece. The pattern used for the printed transfer was an all-over repeat pattern and once applied to the embryo the pattern appeared seamless. Once the annealing process was complete, the form was cut at a precise angle using a formula from my previous work, thus revealing the pattern on the inside of the form. Prior to cutting, the inside of the form was inspected using a torch to identify the seam of the printed transfer. Once identified, the seam was positioned on the front wall of the artwork where it would be least noticeable. The rim was cold worked and polished. Due to the thickness of the layer of clear glass between the white wall of the cup and the printed transfer, the pattern appears to be floating within the inside of the form.

The white form, where the pattern appears on the outside of the piece, was created using a casing process but unlike the process described above, it did not involve a cup. An embryo consisting of black glass encased in white glass and subsequently embedded in clear glass was used as a vehicle for the printed transfer. Due to acquired knowledge of working with the ovoid form, it was felt that the printed transfer pattern should be adapted to complement the form. The image was, therefore, modified by cutting it into strips that could be applied separately to the embryo, thus reducing any creases in the transfer that can occur when fitting two-dimensional imagery to the contours of a three-dimensional form. Particular care was taken not to cover the base of the embryo as the pattern can be rubbed off during the pick up process due to the downward pressure when attaching the blowing iron.

One aim of this artwork was to explore whether screenprinted transfers could be successfully embedded on the inside of blown glass forms. This was successfully achieved using the cup-casing process. Even though it was not possible to view the imagery once it had been placed into the cup, there was minimal stretch and distortion of the imagery. However, the imagery had faded during the blowing process. With the white ovoid form, the strategy of cutting the imagery into strips prior to application did minimise creasing of the screenprinted transfer and produced artwork with minimal imperfections.

5.9 The secret lies within

'The secret lies within' (2008), was concerned with considering a more three-dimensional approach to relief and intaglio printmaking. The method was developed as a response to hand-carving a plaster block to create a patterned roll-up sheet (See 4.4). During testing I realised that there was potential for not only producing pattern but also for producing textured pattern. The intention was that once the textured sheet had been rolled-up, the artwork could either be viewed as a whole with the texture visible through the smooth exterior surface or the artwork could be opened up to reveal the texture within.

Figure 99 'The secret lies within' 2008 Kiln formed three-dimensional textured glass sheet rolled-up to form textured glass egg

'The Secret Lies Within' (Figure 99) was created by hand-building a clay sheet incorporating a three-dimensional repeat flower pattern. A plaster mould was taken from the clay sheet (Figure 101). A gel flex mould was taken from the plaster in order to enable reproduction of the sheet at a future date (Figure 100). Clear Gaffer glass frit was used to infill the mould. The mould was placed in the kiln and fused together to form a three-dimensional glass panel.

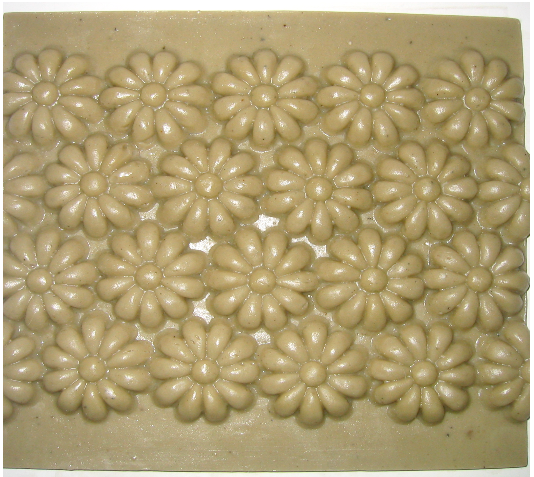


Figure 100 Gel flex former of repeat flower texture.

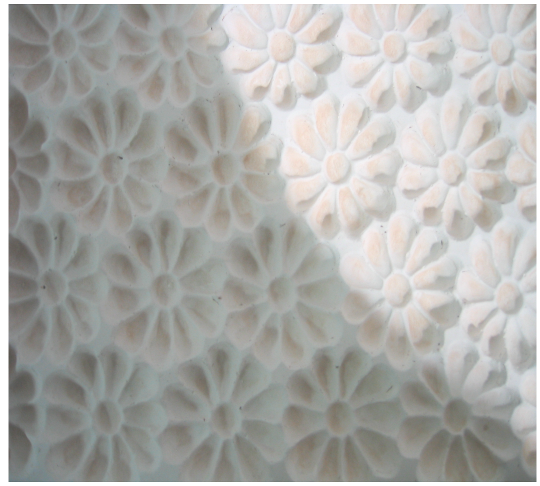


Figure 101 Plaster/molochite mould taken from gel flex former.

The panel was placed texture side up on a batt washed kiln shelf and pre heated slowly in the lehr. At approximately 560ºc the shelf and panel were picked up on a pastorelli and heated further in the glory hole. A collar was prepared on a blowing iron and, once the sheet reached a temperature where it could be shaped, the collar was rolled along the flat edge of the panel with the texture on the inside. The edges of the panel were joined using tweezers, forming a seam down the side of the piece. The end of the piece was jacked in to seal it and the piece was blown and shaped to form a parison shape. A layer of clear glass from the furnace was gathered over the parison and the piece was jacked in to form a cut line and blown and shaped into the final ovoid shaped form. Once the piece had been annealed in the lehr, it was cut in half to reveal the textured flower pattern. The edges of each half were highly polished and mounted on a marble base.

This process was successful in creating blown glass artwork with a textured surface. However, although still acceptable the depth of the texture was compromised during the blowing process.

5.10 Something patterned from something plain

'Something patterned from something plain' (2008), is a flat glass panel made from recycling my own off-cuts of blown glass (Figure 102). The off-cuts were arranged onto a batt washed kiln shelf with batt washed kiln shelf dams placed around the edges making a frame shape for the glass to be melted in. The pieces were fused together in the kiln to create the panel. With this artwork it was not the process of making the panel that was relevant to the research but what I subsequently created from the panel.

Figure 102 Something patterned from something plain 2008 Glass panel made from recycled off-cuts of blown glass - 80 cm x 55 cm.

As the intensity of the pattern created by the melted off-cuts was reminiscent of fabric, collaboration with a fashion designer was negotiated. The aim of the project was to explore digital printmaking processes capable of turning a digital print of a small section of the glass panel into lightweight printed silk fabric that the fashion designer could use to make a range of garments.

Figure 103 'Acid Lights' 2009 Close-up section of glass panel used to create digitally printed silk and examples of garments produced from digitally printed silk in collaboration with fashion designer Kirsty Doyle.

Creating the ‘acid lights’ collection gave valuable insights into how digital technology could be used to facilitate the crossover of textiles and glass, a common theme in my artwork (Figure 103). The glass panel was produced to decorate a personal space whereas the garments were produced to decorate the body of the wearer.

5.11 Summary of Chapter 5

The decision to create artworks as part of this research was to demonstrate the decorative potential of using the creative print inspired processes of combining blown glass and print. It was important that the creative print inspired processes were capable of producing high quality artworks that were part of my ongoing studio practice e.g artworks suitable for sale or for exhibition purposes. The success of these artworks was defined by personal judgment, as well as how they were perceived by a wider audience and other professional glassmakers. Judged under these conditions, the artworks fitted the purpose as they have subsequently been exhibited at various venues including the British Glass Biennale 2010 (‘A Little Bit Of Lace’ – Figure 95 and Every Picture Tells a Story – Figure 86). In this way the methods of production used to create the artworks were brought to the attention of other glassmakers as well as to the general public.

Successfully combining glass and imagery to produce these artworks was reliant on adhering to the technical rules associated with forming glass. In addition, it involved successfully blending craft skills, systemic testing and creative exploration with visual qualities that would appeal to an audience. The processes used to make the artworks were perfected through experimentation whilst the choice of imagery used in the artworks was based on my personal inspirations and creative instincts as an artist. The aim of this research was to develop and use print inspired creative processes as a tool for the production of visual qualities that contribute to the decoration of blown glass forms.

When retrospectively evaluating the creative processes developed and used to produce these artworks for their decorative potential, it became apparent that it was possible to create a variety of imagery using these creative print inspired processes. However, certain processes were more suited to particular styles of decoration.

When attempting to reproduce photographs as in ‘Every picture tells a story’ (Figure 85), the photopolymer plate process was the most successful as opposed to direct screenprinting and fusing glass powder on to sheet glass or using printed transfers. This was because the photopolymer plate process gave an authentic visual quality similar to the original photographs. The imagery became part of the object rather than it simply being applied to the surface of the object. This process of creating decoration falls in to the category outlined in chapter 2 where decoration made from glass was subsequently used to create a form. One factor to consider with the photopolymer plate process is the complex stages that would be necessary if a varied colour palette was required. This is because it would be hard to in-fill specific colours into specific areas whilst successfully removing the excess glass powder without it filling the areas not required.

For producing imagery that requires a larger repertoire of colours, the method of screenprinting and fusing multiple layers of glass powder onto layers of sheet glass that are subsequently rolled-up, gathered over and blown has advantages. This is because, similar to screenprinting, it is possible to include multiple colours in one image. In screenprinting this is achieved by making a different screen for each coloured element of the image. Each colour has to be allowed to dry before another colour is printed. When applying this strategy to sheet glass, each coloured layer has to undergo a kiln firing to adhere the glass powder to the surface of the sheet. There are very limited processes for decorating blown glass that would have allowed me to achieve the visual qualities found in the Perpetual Pattern series where there is a strong link between imagery and form. The glass imagery creates the glass form but the glass form dictates the overall presentation of the imagery.

These creative print inspired processes could allow other artists to consider alternative ways of working whilst using their own visual language to produce decorative art. By offering alternatives to screenprinted transfers, a greater range of visual effects can be achieved.

6. Conclusions and areas for further research

Chapter 6 draws together the conclusions of the research and connects them to the aims and objectives developed at the beginning of the research study. It details the benefits of the creative print inspired glass processes for use by other artists. It identifies the original contribution to knowledge and suggests areas that would benefit from further research.

6.1 Conclusions relating to aim and objective 1

Aim 1 - To clarify and visually document the limitations encountered when embedding screenprinted transfers into blown glass forms through a series of practical examples.

Objective 1 - To create examples of blown glass with embedded screenprinted transfers to visually demonstrate the defined limitations.

This objective was met as the limitations that can be encountered when embedding screenprinted transfers in to blown glass forms were clarified and visually documented (Figure 36). Two blown glass forms to demonstrate the limitations were created during the demonstrations. In the first form where the transfers were simply embedded into a layer of glass, the documented limitations were not encountered. This was because the form was not subsequently inflated and it is during inflation that the limitations occur. However, in the second form that had been inflated so that the screenprinted transfer was approximately one hundred percent larger than the original size, the limitations of stretch and distortion, loss of density and loss of detail of the imagery were obvious. In previous artwork the limitations had often been subconsciously disguised and hence it was important that the limitations were clarified. The limitations of glass and print compatibility and health and safety issues are not evident in the visual recording of the limitations as they are concerned with the practicality of carrying out the process. However, these two limitations were assessed and the findings recorded in Chapter 3.

6.2 Conclusions relating to aim and objective 2

Aim 2 - To develop and document creative processes of working with glass by drawing inspiration from existing printmaking processes and adapting them for use in the decoration of blown glass forms.

Objective 2 - To identify and test a range of printmaking processes for their adaptability to the medium of blown glass.

This objective was met as a range of creative print inspired glass processes were adapted for use with blown glass and extensively tested for their decorative potential (Chapter 4). The creative print inspired glass processes extended my previous practice of embedding screenprinted transfers into blown glass forms and enabled a wider range of visual qualities to be achieved.

6.3 Conclusions relating to aim and objective 3

Aim 3 - To extend and demonstrate the decorative potential of creative print inspired glass processes as possible models for other practitioners working with blown glass and print.

Objective 3 - To create a body of artwork using the creative processes of combining the two separate disciplines of glassmaking and printmaking.

This objective was met in the creation of a series of both conceptual and functional artworks (Chapter 5). The functional artworks had a use such as a vase whilst the conceptual artworks considered the purpose of the imagery and how it related to the glass form. These artworks demonstrated the diverse range of visual qualities that can be obtained e.g. more detailed pattern, reproduction of photographic imagery, a larger colour palette etc. Some of the creative print inspired processes have been accepted as professional artworks in a variety of contexts (See 6.5)

6.4 Conclusions relating to my own artistic practice

This research has expanded my own visual language through the development of a range of creative print inspired processes that I will continue to use in my artistic practice. One of my own particular inspirations in my artwork is the relationship between glass and fabric and my ability to give glass textile qualities has significantly increased. This is particularly evident in 'Wallflowers' (Figure81) and 'A Little Bit Of Lace' (Figure 94). This research has extended the repertoire of imagery that I can embed into blown glass forms. At the outset of this research I felt that the limitations were stifling my creativity. The creative print inspired processes have allowed me to express my creativity in new and exciting ways. There is scope to extend these processes further in pursuit of the decoration of blown glass forms.

The main limitation overcome as a result of this research is in relation to the density of the imagery post-blowing. This was the limitation I found most disappointing in previous artwork using screenprinted transfers (Chapter 3). Overcoming this limitation has extended the repertoire and complexity of forms that can be produced. In previous practice problems were encountered with artworks cracking. The creative processes developed have eliminated this problem as both the decoration and the form are now made from totally compatible materials. It is now possible to more accurately predict the outcome of my artwork.

The limitation of stretch and distortion was not overcome with the creative print inspired processes. The limitations of stretch and distortion will always be an issue when a blown glass form is inflated as inevitably the imagery will be stretched and distorted, contributing to the loss of detail. However, the utilisation of the roll-up process to transform two-dimensional patterned glass sheets into three-dimensional artworks has improved the limitations of stretch and distortion as well as helping to maintain detailed imagery. It is a process that I will use in my future practice. The roll-up process would have the same benefits if screenprinted transfers were used.

One of the advantages of the creative print inspired processes that I will exploit in my future practice is the ability to produce artwork that has a textural quality. This will focus more on kilnforming processes as the blowing process is not ideal for producing texture.

The artworks created as a result of this research have been exhibited at major exhibitions including the International Festival of Glass British Glass Biennale (2010). This involved the selection of artworks from a judging panel who were looking for innovate glass artwork. It is standard practice for artists to exhibit and present artworks to a wider audience. This often involves submitting artworks for consideration by a panel or artists are specifically invited to partake in exhibitions based on reputation. Both involve artworks that satisfy specific selection criteria that has been determined by experienced professionals. Thus having artworks selected can be viewed as validation and acceptance of processes and ideas. Photographs of the artwork were used in the publicity material produced for the exhibition. Photographs of the new artworks were used to apply for a scholarship to attend the Glass Art Society (GAS) Annual Conference in Seattle in June 2011 and the application was successful. Again the artwork was chosen as being innovative from a panel of glass artists/museum curators and is featured on the GAS website. In addition photographs of the artworks were also used to apply for a scholarship at the Pilchuck Glass School in Seattle in June 2011 and again the application was successful. Finally, the creative print inspired glass processes developed throughout this research have been brought to the attention of the Educational Director of Bullseye Glass in Portland, Oregon and links with the company are being pursued.

6.5 Beneficial outcomes of the research for other practitioners combining glass and print

The range of outcomes can be grouped into five interconnecting categories which relate to the benefits of creative printmaking processes for the decoration of blown glass.

6.5.1 Practical benefits

One practical benefit of the creative print inspired processes for other practitioners is that process 2, process 3 and process 5 allow imagery to be reproduced easily. Sophisticated equipment would not be required with these processes and the artwork can be created using standard equipment commonly found in glassmaking and printmaking studios. This means that the processes could appeal to both printmakers and glassmakers.

All of the processes would be practical for glassmakers as they ensure total compatibility of imagery and form. This is because the glass imagery and the glass from the furnace had the same coefficients. When Gaffer glass was used, Gaffer batch was used in the furnace. When Bullseye glass was used, Bullseye batch was used in the furnace.

6.5.2 Visual benefits

Although this research does not indicate that the creative print inspired processes produce visual qualities that are significantly better than other glassmaking processes used to decorate blown glass forms, it does confirm that they are visually comparable in terms of their decorative potential. In particular creative process 3 and creative process 5 have the ability to produce detailed imagery, photographic imagery, tonal imagery, text, the use of a varied colour palette and texture. Prior to this research one of the limitations I found particularly unacceptable was the reduced density of the imagery following inflation. This was improved using the creative print inspired glass processes and each processes created imagery that was denser compared to imagery created from a screenprinted transfer.

One disadvantage of using screenprinted transfers is that it creates artwork where the decoration appears ‘stuck on’ to the surface of the blown glass form. Creative print process 3, process 4 and process 5 all resulted in a more integrated artwork where the decoration became part of the blown form.

6.5.3. Benefits in relation to health and safety

As the use of solvent-based screenprinting medium was eliminated in the creative print inspired processes, the processes are safe to use and meet health and safety guidelines. Adhering to health and safety guidelines is an important consideration in a studio setting or educational environment.

6.5.4. Environmental benefits

The creative print inspired processes do not require the use of solvent-based printing medium which it turn eliminates the need for strong chemicals for screen cleaning which need to be disposed of safely. This in turn has benefits on the protection of the environment.

6.5.5 Economic benefits

The creative print inspired glass processes are cost effective because a large amount of the making is carried out in a kiln rather than in the blowing studio. This reduces the running costs of the blowing studio and would be reflected in the costing of the artwork.

6.6 Original contribution to knowledge

The contextual review of this research consolidated existing information on combining printmaking and blown glassmaking processes (Chapter 2).

The research offered a number of solutions to overcome/improve my defined limitations. These solutions provided alternative decorative processes to the use of printed transfers (Chapter 3).

The research developed seven creative print inspired glassmaking processes that can be applied to the decoration of blown glass forms (Chapter 4).

The research explored creative print inspired processes and produced a technical guide for use by other artists. Prior to this research little technical information on the process of combining glassmaking and printmaking to decorate blown glass forms was available (Chapter 4).

The research resulted in a body of artworks that demonstrate the creative potential of the creative print inspired processes for combining blown glass and printmaking and highlights the diverse range of visual qualities that can be used to decorate blown glass forms (Chapter 5).

The research extended the repertoire of visual effects that can be achieved when decorating blown glass forms (Chapter 5).

The research introduced an artistic approach that highlighted the crossover between glassmaking and printmaking, adding a fresh and exciting dimension to the decoration of glass (Chapter 5).

6.7 Areas for further research

This research has produced a body of artworks that have been shown to have creative potential in the decoration of blown glass forms. It has also identified several avenues that could benefit from further research.

The use of a varied colour palette during the research was limited as introducing a range of colours would have complicated the processes. However, it is a separate area that warrants further exploration. Blending different colours and layers could contribute to an even greater range of visual qualities for the purpose of decoration.

To assist the viability of the creative print inspired glass processes, new equipment or ways of using existing equipment could be developed and tailored to fit the requirements of the practitioner. This would be in relation to directly screenprinting into the kiln seen in process 2 and process 3.

Experimentation into the application of alternative technologies as a means of improving the creative print inspired glass processes was limited. This was because my expertise is as a glassmaker and integrating new technologies requires a thorough understanding of how they work. Therefore, there is potential for further research that focuses on the utilisation of new technologies in the in the pursuit of decorative blown glass artworks.

To add to the acceptance of the creative print inspired glass processes, it would be advantageous to promote the research both in the UK and overseas. This could be achieved through journal articles, speaking at conferences, developing a website, applying to teach courses in a range of glassmaking arenas, exhibiting the artworks in exhibitions etc. Bullsye Glass expressed an interest in the creative print inspired glass processes. Having the creative print inspired processes recognised by an influential company such as Bullseye Glass confirms that there is potential in the processes. Development and refinement through further research with the support of Bullseye Glass would add important credibility to the processes.

One website identified as a valuable form of documented glass techniques for artists and students was 'VITRA' (2005), a virtual training centre in glass art. Twelve high quality glass techniques from four European countries are documented on this website. Each technique is accompanied by didactical videos and supporting documents. The objectives of the project are to share specific knowledge of partner countries, set up an autonomous information space and promote the use of new technologies (VITRA, 2009). It is disappointing to me that there is no information on the processes of combining glassmaking and printmaking. An aim during further research would be to address this issue.

Appendix 1 The process of glassblowing

Glassblowing is a method of glass forming based on the knowledge that molten glass can be inflated to form a bubble. Cummings (2002) describes how in glassblowing controlled expansion is required as well as constant rotation to prevent the glass from distorting. Bray (2003) describes how air is introduced through a hollow steel tube for the purpose of forming hollow-ware. He states that the term 'glassblowing' also includes reheating and shaping glass, as well as working glass hot from the furnace.

The first step in the process of glassblowing is to gently heat the tip of the blowpipe in the glory hole or the furnace used to keep glass hot. The blowpipe is a hollow steel rod with a mouth piece. When the tip of the blowpipe begins to glow a cherry red colour, it is taken to the glory hole in preparation for gathering or obtaining a layer of glass over a subsequent layer of glass. A gather is taken by dipping the end of the blowpipe into the molten glass whilst rotating it slowly to allow the glass to form a 'gob' like shape on the end of the blowpipe. The blowpipe is then lifted from the furnace. From this point, to ensure that the glass remains centred, it is essential for the glassblower to constantly rotate the blowpipe.

The next step is known as 'marvering'. Marvering is the term used to describe the shaping of the gob of molten glass into a symmetrical shape by rolling the blowpipe in slow even movements across the surface of the marver plate. The plate is usually made from a flat, polished slab of cast steel. Marvering is also used to chill the outer surfaces of the molten glass to provide resistance when blowing. Alternatively the molten glass can be hand shaped by using a hollowed out block or a pad of wet newspaper. The glass is now ready to be formed into the bubble that is known as the parison. Reheating the glass in the glory hole between these stages may be necessary as glass that has cooled down will not inflate.

Air is introduced by placing either a finger or thumb into the mouth at the same time as the blowpipe is placed into the mouth. After a puff of air has been introduced, the end of the blowpipe is sealed with the finger or thumb.

It is helpful to tilt the blowpipe upwards so that the formed bubble can be observed and does not become elongated. From this point steps differ depending on the item required. If a large form was required, subsequent gathers of glass would be needed. The parison would need to be cooled before each gather and reshaped. The process could be repeated several times until enough glass had been gathered. Once a parison of the required size has been obtained, the glassmaker works in a special glassmaker's chair (bench) to 'neck in' the form. Basically this means reducing the end of the blown glass to create a bottle neck. It involves rolling the iron up and down the arms of the bench whilst steadily squeezing the glass with jacks (a tool which resembles large tweezers) just off the end of the blowing iron. Depending on what form is required, various steps could be followed before transferring the parison to the punty or receiving pipe. The parison could be distorted, either by holding it down and swinging it from side to side to stretch it or by holding it up to make it squat. Decoration can also be added at this stage. For example, clear or coloured glass could be picked up or gathered then trailed around the form. Prunts, stems and feet could be added or the form could be blown into a mould.

Transferring the parison to the punty or pontil rod involves the preparation of a small gob of glass on the end of the punty iron which has been rolled into a cylindrical shape. In order that the glassblower can keep the base of the parison hot (ideally the same temperature as the punty), the punty is normally prepared by another glassmaker. The punty is then attached to the base of the parison and transferred by chilling the neck in line with jacks and tapping the iron so the glass breaks at this point. It is essential to rotate the iron in order to keep the form centred.

Work can now be carried out on the rim of the piece either by trimming it back using shears or opening it out by inserting the blades of the jacks into the opening and applying upward pressure whilst rolling the iron up and down the bench. The completed form is knocked off by tapping the punty iron. The piece is placed in an annealing kiln (lehr) which is the equipment used to cool down the piece at a controlled rate to prevent stress which could result in cracking of the glass (Bray, 2001, pp.50-53).

Appendix 2 Table showing research methodology used by other artists undertaking practice-based Ph.D research

1	Discipline
2	Artists who undertook laboratory experiments
3	Artists who undertook testing of processes
4	Artists who undertook evaluation using semantic differential methods
5	Artists who included case studies in their research
6	Artists who included interviews in their research
7	Artists who used a database
8	Artists who produced models
9	Artists who used risk methodology
10	Artists who used visual documentation
11	Artists who undertook historical research
12	Artists whose these included illustrated written text
13	Artists who presented tests and designs
14	Artists who presented artworks
15	Artists who presented their work in a publication
16	Artists who produced a video
17	Artists who had a final exhibition
18	Artists who produced a CD Rom
19	Artists who produced specific products

Area/Researcher	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Julian Malins	C	Yes	Yes	Yes								Yes		Yes		Yes			
Eleanor Wheeler	C	Yes			Yes	Yes						Yes					Yes		Yes
Laura Johnston	**G**	**Yes**			**Yes**							**Yes**		**Yes**			**Yes**		
Katie Bunnell	C	Yes					Yes											Yes	
Justin Marshall	C	Yes																Yes	
Kevin Petrie	C	Yes	Yes									Yes					Yes		
Ray Flavell	**G**	**Yes**							**Yes**	**Yes**								**Yes**	
Richard Slade	C	Yes	Yes									Yes	Yes						
Carole Metcalfe	C	Yes	Yes									Yes	Yes						
Tyra Oseng	**G**	**Yes**	**Yes**									**Yes**	**Yes**	**Yes**					
Natasha Mayo	C		Yes									Yes		Yes					
Babette Martini	C		Yes									Yes		Yes					
Andrew Livingstone	C		Yes									Yes		Yes					
Bonnie Kemske	C		Yes									Yes		Yes					
Neil Brownsword	C		Yes					Yes			Yes	Yes		Yes					
Hayley Daniels	C		Yes									Yes		Yes					
Claudia Clare	C		Yes									Yes							
Alasdair Bremner	C		Yes									Yes	Yes	Yes					
Wayne Strattman	**G**		**Yes**									**Yes**			**Yes**				
Jessemy Kelly	C		Yes		Yes							Yes							
Aaron McCartney	**G**							**Yes**				**Yes**		**Yes**		**Yes**			
Ross Head	**G**							**Yes**				**Yes**	**Yes**						
Vanessa Cutler	**G**							**Yes**				**Yes**	**Yes**	**Yes**					

(Kelly 2010)

Appendix 3 The processes of printmaking

Printmaking processes essentially involve transferring images from one form of an inked up surface (matrix) to another, normally paper. With the exception of monotype, printmaking is a process capable of producing multiple copies of original artwork (Printmaking Vocabulary and Concepts, 2009). Stobart (2001) identified six basic methods of printmaking: monotype, relief, intaglio, screenprinting, lithography and digital printmaking. Four of these processes were relevant to the research and have been defined. The remaining two processes (lithography and monotype) were not considered suitable for combination with hot glassmaking processes.

Relief printing is a method of printmaking where bold shapes and strong marks can be obtained. It involves cutting into a surface to obtain an image. The uppermost part of the surface is inked up and printed from. Many materials are suitable for cutting in to, including linoleum, wood, cardboard, plastic, vinyl, potato. Printing from a relief block does not always involve the use of a press and prints can be achieved through burnishing the back of the paper with a roller or spoon once it has been placed on top of the cut surface (Stobart, 2001, p.19).

Intaglio printing is the opposite of relief printing. An intaglio print is obtained from transferring ink from the lower levels of the plate. An etching or mangle press is needed to force the paper into the depths of the plate. Intaglio plate-making processes include etching, aquatint, engraving, mezzotint and dry-point. Etching is applying a resist known as the ground to a metal plate that is subsequently exposed to acid or corrosive salt. It results in the exposed areas of metal being corroded away. Aquatint is the sprinkling and fusing of resin particles on to a metal place before the plate is exposed to a strong acid known as the mordant. Acquaints can be used to create a variety of tonal effects. Engraving requires a tool called a ‘burin’ to cut into the surface of a copper plate before printing. Mezzotint is a process where the surface of the plate is pitted using a tool called a raker. This creates tiny dots to hold the ink during the printing process.

Other areas of the plate can be burnished to create lighter areas when printed. Mezzoprint is useful when tonal effects are required. Drypoint involves using a sharp point to scratch into a metal plate, plastic sheet or specially coated card.

Screenprinting involves the application of a stencil to a mesh surface known as a screen. Ink is dragged across the surface of the screen using a rubber blade known as a squeegee and the printed image emerges from the non-stenciled areas. There are various methods of stenciling the screen ranging from paper stencils to photostencils. Photostencils require covering the screen with a photosensitive emulsion then exposing a drawn or photographic image onto the mesh using an ultra-violet light box (Stobart, 2001, p.76). The photosensitive emulsion hardens when exposed to ultraviolet light.

In the 1990's there was major shift in the use of screenprinting as an artistic process following health and safety concerns in relation to the solvent based chemicals used during the printing process. Water-based screenprinting was developed to create safe working conditions (Hoskins, 2001, p.9). Art schools in the UK were encouraged to adopt water-based processes rather than solvent-based processes to meet the guidelines documented in the Health and Safety at Work Act and Control of Substances Hazardous to Health regulations (COSHH). Hoskins (1991, pp.9-11) states that using a solvent-based process instead of a water-based process was not easy as it was not simply a case of changing the brand of ink used. In reality water-based screenprinting is a completely different process with only a few common elements to solvent-based screenprinting. Water-based screenprinting involves different methods of creating stencils, different methods of printing as well as using different types of paper to print on. This meant initial acceptance of water-based screenprinting was met with resistance, heightened by the fact that, even though the process was advantageous for health, artists were often disappointed with the quality of the printing. Hoskins believes that this was more of a mind set rather than a failure in the quality of water-based products.

Digital printing is the process by which images are digitized. This involves translating them into a matrix of dots called pixels. The digitised imagery is used to digitally control the ink, toner or electromagnetic energy to reproduce the imagery. Digital printing offers a quicker response time due to its minimal press set-up and built in multi-colour registration system (What is Digital Printing ? n.d.).

Whale and Barford (2001, pp.9-11) state the use of computers offered new techniques for combining and manipulating imagery and allowed printmakers to utilize many different sources in their work, potentially dissolving the boundaries between printmaking and other forms of artistic and scientific expression. In addition computers allow artists to promptly turn their creative ideas into prints. Whale and Barford acknowledge how artists worldwide have used their imagination to adapt computer technology for creative use.

Some artists adopt an ‘all digital’ approach in which the finished print is created through the use of a digital device such as an ink-jet or laser printer. In contrast other artists have adopted a more ‘hybrid’ approach through inventively combining digital outputs such as film positives or machined metal plates with traditional printmaking media.

Whale and Barford believe digital printmaking involves the print taking the form of a physical object (something that can be held in the hand) and that human creativity is paramount to the process, a comment which is relevant to this creative practice-led research combining glassmaking and printmaking processes

Appendix 4 Brief overview of the history of glass processes and decorative trends in blown glass

The history of hot glass and decoration is extremely long and complex, spanning many centuries and encompassing many countries. At times there was evidence of major developments in both the glassmaking processes and the closely related decorative tradition. At other times there were periods of decline, often reflecting the prevailing economic climate, current social values and particular aesthetic preferences of the period.

Prior to the development of glassblowing in Roman times, two documented techniques used to produce and decorate glass were core-forming from c.1650 B.C. and mosaic casting from c.1500 B.C. (Forge, 1991). Core-forming is one of the earliest documented examples of the production of decorated hollow glass forms. Core-forming involved the forming of a core on a metal rod made from a mixture of sand, clay and camel dung. A layer of glass was subsequently applied to the core either by winding trails of hot glass around it or dipping it into molten glass. The core was removed from the glass vessel form once the glass had been cooled (Bray, 2001). Mosaic casting where multi-coloured glass canes were produced and cut into small sections, facilitated the production of decorative glass.

Early Pre-Roman work featured simple spiral thread decoration. This was followed by more elaborate zigzags and spirals and subsequently even more elaborate rosettes, flowers and scrolls. Around c.900 B.C. decoration again became more simplistic, taking the form of engraved marks and wheel cut horizontal ridges. During the wealthy Hellenistic age, gilding was introduced as a form of decoration. The imagery prevalent at this time included the human figure, animals and hieroglyphic symbols (Forge, 1991).

During 1st century A.D. floral and figural work in relief became fashionable. In the second half of the 1st century, colourless glass became popular. This allowed the cutters to take full advance of the optical qualities of the medium of glass.

The cutters began to experiment with decoration consisting of abstract patterns, lines and circles.

During 2nd century A.D. decoration became more figural, depicting scenes and pastimes of the period, natural subjects such as animals and mythical creatures. The 3rd century A.D. saw the introduction of inscriptions. An example of blown glass and decoration from the late 3rd to the early 4th centuries A.D. exists in a series of bottles produced with pictorial maps of two seaside resorts (Newby, 1991).

Cummings (2002, p.1) states that decoration during the Roman period was divided into two categories. The piece could either be decorated whilst it was hot (Vitrearii). Alternatively the decoration could be applied once the piece was cold (Diatrearii).

Hot decoration included coloured trails, vertical or spiral ribs, blobs or speckles, thick coils, chunks or fragments of glass left in relief, pre-formed press moulded medallions and other shapes. Cold decoration included cutting, engraving, grinding and polishing. This was carried out by experienced glass cutters who had the skills to cope with the constantly changing Roman fashions.

The Romans were responsible for establishing several glassmaking processes and techniques for decoration, many of which are still in use today. Types of blown and decorated glassware produced during the Roman period were gold glass and painted glass. The gold sandwich, where gold decoration was trapped between two layers of glass, probably emerged during 4th century A.D. (Newby, 1991). This is an example of encasing decoration into layers of glass. Gold decoration was precious and trapping it enabled the decoration to be protected. Gold sandwich glass made a re-appearance in Bohemia in 18th century. The luxurious gold and silver foiled vessels often carried decorative motifs, hunting and garden scenes, religious subjects and armorials (Wood, Mortimer, Priestley, 1991).

One important influence in the history of decorative Venetian glass came from Chinese porcelain. Imitations of the decorative porcelain were produced in glass and in c.1475 a patent was granted for the production of glass porcellano.
The opaque, white coloured glass used specifically in the production of porcellano glass was called ‘lattimo’, derived from the Italian word meaning milk (Sheppard, 1991). The British utilized a variation in opaque white glass. The addition of arsenic to the glass rather than tin created a solid dense white that did not change in transmitted light (Wood, Mortimer, Priestley, 1991).

The latter part of the 17th century was a period of technical experimentation as well as a period rich in the decorative arts. The glassmakers of North Western Europe were influenced less and less by Venetian techniques and began developing their own indigenous styles. A movement called Baroque, which spread from Italy to France and subsequently to the rest of Europe and many other countries worldwide, was responsible for the Baroque style decoration in glass that emerged at the end of 17th century. The Baroque style favoured by the Court of Louise XIV encompassed grandeur and theatricality and works of art were produced to appeal to all the senses. Baroque style glass can be linked with the perfection of the potash-lime recipe. This type of glass was used to produce the thicker more ductile glass vessels from this era. The decoration of the glass was carried out through grinding, carving and engraving the thick glass vessels, giving the object a dramatic three-dimensional quality (Wood, Mortimer, Priestley, 1991).

A parallel movement to Baroque called Rococo appeared in Europe (particularly France) in the mid 18th century. Rococo style glass introduced asymmetrical scrolls, shell-work and scales into the plethero of engraved imagery already being produced. Rococo decoration was concerned with lightness, elegance and delicacy. It had a decorative charm and the loose but elegant decoration was developed as a reaction to the formal, heavy atmosphere of Louis XIV’s court (Wood, Mortimer, Priestley, 1991).

Bohemia saw the adaptation of enameled decoration to that of a Rococo style, especially on opaque white glassware. However, this particular fashion was thought to have been demoted throughout the century to a peasant craft, producing items such as schnapps flasks decorated with stereotypical motifs in a limited colour palette (Wood, Mortimer, Priestley, 1991).

In the 18th century reference was made to a particular type of glass named lead glass. Lead glass is a term that can be associated with George Ravenscroft in England.
Even though Ravenscroft is no longer credited with the invention of lead glass, he is still credited with providing England with some of the finest examples of glass for vessel making. Ravenscroft experimented with adding flint and lead oxide as a flux to the furnace glass recipe in the hope of creating a heavier more brilliant type of glass. The encompassing of this new material resulted in a plethora of fine objects, including hemispherical ribbed bowls, wide hollow stems set with prunts, ceremonial cups embellished with pincering, trailing and other applied ornament. The ductility of lead glass led the glassmakers of England to abandon the delicacy of foreign styles, giving way to more substantial designs. Inspiration in form was taken from contemporary fashions in silver and furniture with designs reflecting turnery and strength (Wood, Mortimer and Priestley, 1991).

During the 19th century Britain emerged as one of the leaders in the glass manufacturing industry (Wolfenden et al, 1991). Regency style cutting was introduced in 1825. The Regency style was based upon horizontal bands or panels of deeply cut motifs with the addition of tall, vertical, flat cut slender or broad flutes. The popularity of the Regency style declined around 1840.

Art glass was a term given to the range of glass produced in Britain between mid 1870 and 1890. Art glass embraced decoration and was produced for the wealthy public with conservative tastes. It included high quality ornamental vases and vessels and was once described in a poster for a glassmaking firm in Stourbridge in 1889 as ‘Works of Art in Sculptured Glass’ (Wolfenden et al, 1991).

Art glass can be loosely placed into three categories; glass with applied ornament, glass reliant on colour effects and glass with internal or surface decoration. Cold decorating skills were also applied including engraving, carving and enameling. Another term synonymous with 'art glass' is 'fancy glass', which is essentially a cheaper version of art glass.

An interesting trend attributed to mid 19th century was the reproduction of objects from other periods. Objects created in this manner became known as 'Historismus'.
Some of the most well known examples saw the revival of Venetian and German styles including complicated cane worked stemware and vases as well as replica Humpen beakers and Hochschnitt goblets (Wolfenden et al, 1991).

The Rock crystal technique of 19th century was characterized by deep detailed engraving, highly polished in the manner of cut rock crystal. The polished detailing was sometimes teamed with interwoven cut patterns and etching. Its popularity was short lived as a bid to reduce production costs saw some of its effects replaced by mould-blown patterns (Wolfenden et al, 1991,). A similar process that existed parallel to rock crystal was labeled 'brilliant cut glass'. The name of the technique reflected the appearance of the pieces made using the process. The process of brilliant cutting originated in America but British examples exist from late 1870-1880 (Wolfenden et al, 1991). The process involved the use of a cutting lathe with different grades of abrasive and polishing wheels to create the decoration (Bray, 1995).

Glassmaking in 19th century was transformed as a result of the Industrial Revolution. A more scientific approached was adopted and glass furnaces were standardized. The consistency of the glass being produced was more suited to the demands of mechanical cutting and the involvement of chemists in the glassmaking process saw a greater variety of colours in the production of glass. The shapes and patterns produced in the second half of the 19th century were consequential to the international trade of books illustrating designs from antiquity (Wolfenden et al, 199l).

Casing was one process made possible through the adoption of a more scientific approach to glassmaking which involved controlling the coefficient rates of expansion and contraction of the different coloured glass used. If the coefficients of the coloured glass did not match, the vessel would crack. Wolfenden et al (1991, pp.131-132) claims that casing was used as it produced a thicker coating than staining and also allowed greater scope for cutting and engraving. They felt that better quality cutting was reserved for the better quality object and the poorest examples of engraving from the 19^{th} century were on stained rather than cased glass.

Appendix 5 Brief history of important developments in glassmaking processes used to decorate blown glass forms

Hot glass and enamel

Decorative enameled glass was first produced during the Roman period and involved firing brightly coloured enamels to fuse them to the outside of the vessels. (Newby 1991). Early enamel consisted of combining particles of glass with suitable colourants and fluxes (Bray 2001).

The Aldrevandin enameled beakers produced in Germany and Switzerland during 13th to 14th century are an interesting juxtaposition of mid-medieval glass. They are decorated with religious figures, secular scenes, birds, animals and heraldic motifs. In this work the process of enameling is undoubtedly Islamic in origin yet the imagery used on the beakers is European in style (Whitehouse,1991).

During the 15th - 16th century the Venetians were important players in the production of enameled glass. A significant development for the Venetian glass market was the export of glass to other parts of the world, particularly Germany and Northern Europe where it began to cater for local tastes. The production of commissioned vessels decorated with enamel, commemorating marriages became popular. In Germany this resulted in the production of a more robust form of enameling.
An example of this style of work included the large cylindrical beakers called Humpen. Humpen are elaborately enameled drinking vessels adorned with imagery from various subjects that might be toasted to. Decoration included the Reichsadler, portraits of kings and princes, religious subjects, fables, musicians, armorials and erotic subjects (Sheppard,1991).

Bohemian glass of 19th century was concerned with the development of transparent enamels resulting in the production of stained and coloured case glass. Samuel Mohn, a porcelain painter, began experimenting with this technique in 1806. He later announced his discovery of the lost art of transparent painting on glass. Mohn's skills were passed on to his son who in time influenced others in the technique.

The quality of transparent enamels on glass can be compared to the use of soft watercolours (Wolfenden et al, 1991).

Hot glass and print

The introduction of printmaking for use in the application of enamel to a glass surface did not emerge until the 18th century. One of the earliest surviving examples of a printed glass flask is on display in the Victoria and Albert Museum in London and is dated between1760-1770. The flask contains the black printed imagery on both the front and back of the vessel. Further decoration has been applied to the prints through coloured hand-painted enamels. Petrie notes in this example that there is a lack of consideration between the image and the form as the image does not fit the flask. Petrie speculates that this may be because it is one of the first examples of printing onto glass (Petrie, 2006).

In 1845 excise tax on glass was removed. This spurred glass manufacturers into experimenting with new techniques and promoting new lines. Wolfenden et al, (1991, p.109) documents how two companies produced transfer printed enameled wares, namely George Bacchus and Sons of Birmingham and W.H.B. & J. Richardson of Wordsley (near Stourbridge).

Issitt (2008) in his article on Bristol Glass claims that English printers from either Battersea or Liverpool were the pioneers of this technique. Saddler and Green were a printing company in Liverpool who originally specialized in engraved prints. They were responsible for the majority of opaque transfer printed glass produced in Bristol. Issitt describes transfer printing as the transferal of an image from a copper plate to glass, pottery or enamel by the means of a paper transfers. The process involved inking an engraved copper plate with ink prepared from a metallic oxide and then transferring the design to paper. Whilst the pigment was still wet, the copper plate was pressed onto the glass to leave an imprint. This was subsequently fixed by firing. Issitt also claims that the process of applying this type of decoration was carried out by painters, enamellers and guilders employed within the pottery and porcelain industry as opposed to glassmakers.

He does make particular reference to one glassmaking company, Henry G Richardson & Sons of Stourbridge who were renowned for this particular type of decoration.

Another type of printing that has been utilized for use with glassmaking entails screenprinting layers of enamel onto a special type of paper known as transfer paper. Once the enamel is dry the transfer can be applied to the form and subsequently fired.

Bray (1995, p.233) refers to transfers or decals as having been commercially prepared for use in the decoration of mass-produced domestic wares. In a later publication Bray (2003, p.92) expands by stating that transfers can be applied to vertical or flat of complex curves as a means of transferring enamel to a glass surface. Bray also recognises that transfers can be applied to a flat surface and subsequently picked up on a suitable gather and blown out to distort the imagery.

Hot glass and engraving

There is preserved evidence of innovation in engraved luxury glass decoration from the Roman period. Two of the most spectacular examples of engraved glass form this period include the Lycugus cup and the Portland vase.

The Lycurgus cup is an example of a particular style of engraving from the late Roman period that resulted in the forming of a cage cup. Cage cups were made by carving a relief lattice from a thick walled blank (either blown or cast). The lattice or cage was undercut, allowing the decoration to stand out from the main body of the vessel being attached by small hidden glass bridges (Bray, 2001). The Lycugus cup, which depicts the death of Lycugus, is a good example of the cage cup technique. In transmitted light the colour changes from a dull green colour to a transparent wine colour (Bray, 2001). There is some debate as to exactly how cage cups were made but it is clear that they demanded craftsmanship of an extremely high standard. Bray (1991 p.62) states that the glass could easily be broken by the slip of the hand or by misplacing the grinding wheel.

The Portland vase (c.30-20 B.C.) is a fine example of cameo glass. Newby (1991, p.31) speculates that the Portland vase was formed by repeatedly dipping a gob of blue glass into molten, opaque white glass to build up an outer layer before it was blown into shape. The blank was passed to a master gem-cutter who carved away the layer of white glass to leave the decoration standing in relief. The development of wheel-engraved decoration as opposed to the previously favoured diamond point engraving, originated in Germany in 16^{th} century. Foot treadles or water mills were utilised as a power supply to turn the different sized copper wheels, which were used with an abrasive to cut the glass. Different sized and shaped wheels were used to create various aesthetic effects, including areas of clear or opaque glass, areas of high relief and areas of different sized intaglio. Wheel engraving spread to other areas such as the Netherlands, highlighting its popularity, which continued in to 18^{th} century (Sheppard, 1991).

During the 18^{th} century stipple point engraving emerged as a variation on wheel cut engraving. The process involved using a sharp diamond or tungsten point to tap the surface of the glass, thus creating dots. Carefully controlling the depth and density of the dots resulted in light and dark shaded effects (Wood, Mortimer, Priestley, 1991).

Hot glass and etching

In the middle to low glass markets, engraving was replaced or used in combination with acid etching. John Northwood significantly contributed to the development of the etching process by producing a template machine for outlining figures and complex linear designs. The template machine used a needle in a wax coating to outline the decoration, which was then exposed to the acid (Wolfenden et al, 1991).

Hot glass and frosting

Around 1840, frosted glass became popular. Some of the frosting was achieved by rubbing the surface of the glass with an abrasive (Wolfenden et al, 1991). The origin of graal as a process can be attributed to Orrefors glass factory and was developed by Simon Gate and Edward Hald.

Hot glass and the roll-up process

Early examples of turning two-dimensional sheets to three-dimensional forms can be seen in the work of glassmakers from Western Europe who used Reticella canes. The canes were produced by twisting together at least two different coloured glass rods. Reticella rods were used to decorate jewellry in 7th century A.D. and subsequently to decorate glass vessels throughout 9th and 10th centuries A.D. (Whitehouse, 1991)

The Venetian glassmakers were responsible for the development of various new ways of working with hot glass and decoration. One method developed in 16th century was a hot process and involved working with glass canes. This process was named Filigrana. Filigrana consists of forming long lengths of canes, which are subsequently cut into suitable lengths. These are placed and heated together on a metal plate. A glass disc is formed on the end of a blowing iron and rolled along the edge of the cane to pick them up. The marver is used to shape them into a cylindrical form. The end of the cylinder is closed and the canes blown and worked to achieve the required form (Bray, 2002).

The process of Filigrana became highly developed by the Venetians and there were many different ways of working with the cane, resulting in a myriad of decorative techniques. Each different method of working the cane inherited its own title. 'Vetri a Reticello' is one example demonstrating the significant developments the Venetians made to working with glass cane. Reticello gives the appearance of an elaborate net formed in glass. The effect is achieved through criss-crossing networks of canes and the subsequent trapping of air bubbles (Sheppard, 1991).

Glossary

Acid etching	Removal of areas of glass by applying acid to areas not covered by some form of resist.
Annealing	Glassmaking process where a hot glass item is uniformly heated and gradually cooled down over a long period in the lehr to toughen the glass and reduce cracking
Applied decoration	Term used to describe a decorative addition applied to the hot glass form.
Architectural glass	Term used to describe glass used in building construction. It is often used to described stained glass.
Art glass	Ornamental rather than functional glassware.
Batch	Mixture of raw materials that are melted and fused together to make glass.
Bat wash	Material applied to kiln shelves to present sticking. There are several materials available for the purpose.
Blown glass	Glass objects that have been created through the glassblowing process.
Bullseye glass	Bullseye Glass Company is a leader in promoting glass art worldwide through quality production of colored glass for art and architecture and research.
Cameo glass	A technique in which the finished glass form is covered with another coating of glass of a different colour into which it carved or etched a design which exposes the base colour
Cased glass	Blown glass where one layer of glass is applied over another layer.
Cast glass	Artwork produced by forming the glass in a mould.
Co-efficient	Increase over a specific range of temperature rise
Cold working	Process used on cold glass e.g. engraving, grinding
Collar	Band of glass applied around the rim of a bottle or open vessel

Compatibility	In glassmaking a reference to differences in co-efficient of expansion rates between materials that causes visible cracks or stresses when they are heated together.
COSHH	Legislation covering the control of substances hazardous to health. In recent years this legislation has impacted on the use of solvents in industry and education.
Cover-coat	Layer of organic material that encapsulates the colour and burns away during firing.
Cup casing	Process of making a cup of coloured glass into which a gather of clear glass is introduced.
Decal	Another term for a transfer.
Decorative	Embellished or adorned artwork.
Diamond engraved	The use of a diamond point for engraving.
Digital printing	A method of printing from a digital based image directly on to a variety of media.
Enamel	A material made from various coloured opaque or transparent pigments composed of glass powder, metallic oxides and a flux such as borax.
Enameling	Process of applying enamels on to cold glass.
Engraving	Technique of cutting into the surface of the glass.
Encased glass	Objects made from glass that are covered with an outer layer of clear glass.
Etching	Process of matting or removing a surface of glass by exposure to hydrofluoric acid or its derivatives.
Firing	Process of heating a ceramic or glass item in a kiln at a high temperature.
Flat glass	Sheet glass commonly used for windows.
Folex	Direct screenprinting emulsion for water-based printing onto paper and board. The emulsion has a wide exposure latitude and it is easy to decorate with chemicals.

Form	A shape.
Free blown	Alternative term for hand-blown.
Frit	Batch material that has previously been melted and ground up into different size particles.
Frosting	General term for a variety of matt finishes
Functional	Capable of serving the purpose for which it was designed
Fusing	Process of heating glass elements until they are fused together.
Glass blowing	Glass-forming technique where air is introduced in to the glass to form hollow ware.
Graal	Decorative glass technique developed by Orrefors of Sweden in 1916. The design is carved onto a coloured glass parison, which is then reheated and cased in a thick layer of transparent glass of a different colour, then inflated.
Grisaille	Medieval technique of gray-tonal painting on glass. The technique involves painting and firing vitreous paints onto glass. First the black line work called tracery is painted onto the glass surface and permanently fixed by firing. Then a wash of black paint, called a matt, is applied over the tracery and subtracted by specially shaped bristle brushes. The tonality and patterning (modeling) created by this subtractive process is then fixed by firing.
Hand-blown	Term used to describe an article which is blown and manipulated entirely by hand.
HASWA	Health and Safety at work act (1994). An umbrella under which a variety of individual health and safety acts can be enforced.
Hot glass	Glass worked in its molten state directly from the furnace either by blowing or casting.
Inflation	Alternative word for the technique of glassblowing
Intaglio	Engraving which is cut or incised.

Kiln	Oven used to process a substance by burning, drying or heating.
Kiln-formed	Term for the glassmaking process of fusing, slumping or texturing glass using the heat of the kiln.
Lehr	Type of oven or kiln used for annealing glass.
Limitation	Imperfection or shortcoming which limits an object's use or value.
Lino cut	A relief printmaking process where linoleum is used a as the matrix for the image.
Lost wax technique	An ancient technique traditionally used for the casting of bronze and precious metals but now widely used for casting glass objects.
Medium	Liquid used as a vehicle for holding enamels, lustres and oxides in order that they can be painted or sprayed onto glass.
Molochite	Calcinised china clay used as an investment material in mould making.
Mould	Negative form into which glass is either cast or blown.
Opaque	Impenetrable by light; but not transparent or translucent.
Overlay	Alternative term for cased glass.
Parison	Gather on the end of a blowpipe that is already partly inflated.
Pattern	Repetition of shapes, lines or colours. Also known as motif.
Photo-emulsion	Light sensitive colloid that is coated onto a substrate.
Printed transfers	Printed image used for permanent glass decoration that is transferred from its base paper, applied and fired onto a substrate.
Prunt	Applied roundel of glass added to decorate a blown glass item.

Relief cutting	A process in which the background is removed by cutting to leave the pattern in high relief.
Resist	Substance that resists or prevents a particular action.
Reverse painting	Term applied to a number of decorative techniques, all of which involve painting on the back of a glass object.
Roll-up process	Process that allows vessels to be formed from sheet glass.
Sandblasting	Process of projecting abrasive material by the use of compressed air in order to matt or penetrate the glass surface.
Screenprinting	In glassmaking the process of pressing enamels through a screen to produce repetitive designs on glass.
Squeegee	Rubber blade used in screenprinting.
Slumping	Process of reheating a blank until it becomes soft and flows over a mould and eventually assumes that shape of the mould.
Stress	The force per unit area on a body that causes it to deform the area being perpendicular to the force. The term is used to describe tension in the glass.
Transfer	Design produced in order to be transferred to another surface.
Transfer paper	Medium used to receive the image prior to transfer onto the chosen substrate
Translucent	Quality of a material that allows diffused light to pass through it
Transparent	Quality of a material that allows light to pass through it.
Waterjet cutter	Machine capable of slicing into metal or other material using a jet of water at high velocity and pressure.
Water-slide	Transfer application method where the paper is soaked briefly in water to dissolve the gum coating and allow of the transfer to be applied to the substrate.
Water-soluble	Becomes soluble when introduced to water.

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